OUR DEBT TO THE PAST

OR

CHALDEAN SCIENCE

V. E. JOHNSON, B. A.

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ERRATA.

Page 34, bottom line, *for* ‘phenomena’ *read* ‘phenomenon.’
Page 48, line 15, *for* ‘1 foot’ *read* ‘nearly 1 foot.’
Page 51, line 12, *for* ‘Englishmen’ *read* ‘Englishman.’
Page 103, bottom line but one, *for* ‘a given phenomena’ *read* ‘a given phenomenon.’
Page 110, footnote, *for* ‘Sir David Brodie’ *read* ‘Sir Benjamin Brodie.’
Page 112, line 12, *for* ‘Tydall’s’ *read* ‘Tyndall’s.

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OUR DEBT TO THE PAST.

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OUR DEBT TO THE PAST

OR

Chaldean Science

AND AN ESSAY ON

MATHEMATICS AND THE FINE ARTS

BY

V. E. JOHNSON, B.A.

AUTHOR OF 'THE USES AND TRIUMPHS OF MATHEMATICS'

> 'We are what we are, we possess what we possess, even in the very elements of our knowledge—thanks to the labours of the ancients.'—*Max Müller.*

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PREFACE.

THE favourable reception accorded to my 'Uses and Triumphs of Mathematics' has led to the publication of this little work, in which I have endeavoured to give, in a popular form, a clear, concise, and, as far as possible, accurate account of what modern science, in conjunction with ancient testimony, has revealed to us about the scientific knowledge of one, if not of *the* most remarkable and interesting people of antiquity; and by so doing to illustrate, *not* the superiority of the ancients to the moderns, than which nothing can be more untrue, but to show that those who preceded us by many, many centuries were not devoid of imagination and observation, and that experience and reflection had enabled them to become acquainted with many things of which we moderns would boast ourselves the inventors and discoverers. It is scarcely necessary for me to say that I have freely availed myself of the researches of the most eminent English, French, and German scholars, whose writings have thrown so much light on the ancient people of the East. The reasons given in the Introduction to the Essay on 'Mathematics and the Fine Arts' are, I think, a sufficient excuse for its introduction here.

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OUR DEBT TO THE PAST.

PART I.

INTRODUCTORY.

SOME seven hundred and twenty-one years before our era, there was an Assyrio-Chaldean king, by name Nabonassar, who, desiring that everything henceforth should date from his reign, destroyed as many as possible of the calendars, astronomical lists, etc., etc., which existed when he mounted the throne, thus rendering almost impossible any excursion into the astronomical and scientific knowledge of the ancient Chaldeans.

Now, there are some of those now-a-days who would similarly like to cut those historic fibres by which our present languages, literature, philosophy, cling to their native soil, than which nothing can be more fatal, for it is this handing over to one generation the experiences of another, the establishing of relations between the present and the past, and thus consolidating, so to speak, this consciousness of common responsibility, which constitutes the civilisation of the historical, or the most important races and nations of the world. A study of the past cannot fail to awaken the profoundest interest in all students of history and development of human culture; a study of the past shows us how there were 'great waves of change which spread from country to country, sweeping over continents, and passing away, only to be succeeded by similar waves.' Without an acquaintance with these waves of change, it is impossible for us to rightly comprehend or fitly use the present, for it is only by an intercourse with the past, by holding communion with the great and good of all ages, that we can derive from the experience of these past ages the power of soothing and governing the passions, and of softening the heart, being thereby enabled to comprehend man as he now is, for there is but one key to the present, and that is the past. Now, man is explicable only by means of all his history; no history can be philosophical which does not trace the origin and causes of those 'waves of change' just alluded to. Still less can any history be philosophical, or a history at all, in the proper sense of the word, which does not acquaint us with man's endeavours after truth, things far more worthy of record than 'all the kings and rulers, and battles and dates, which so many people even now imagine to be history.' Without an acquaintance with the history of physics, it is impossible to form a correct opinion of the effect which the study of nature has exercised upon the cultivation of the mind. Children are now taught in our schools truths, the discovery of which cost immense labour and indescribable effort. They have more correct notions of nature and natural phenomena than had Plato. They *may* treat with ridicule the errors which Pliny committed in his natural history. The college youth *can* now smile at Newton's corpuscular theory of light.

Until a few years ago, it was believed that the Greeks were the sole initiators of all culture; that their arts, their sciences, their literature had been created entirely by them, and that they owed nothing, or next to nothing, to those who had preceded them. To-day it is not possible for us to entertain such a theory. Without doubt, it was upon the radiant shores of Greece that ancient civilisation attained its full efflorescence, but it was in the East that it had its earlier developments. We know to-day that, when the old Hellenes were nothing more than ignorant barbarians, brilliant Empires flourished upon the banks of the Nile, the Tigris, and Euphrates. Their knowledge they owed almost entirely to the Egyptians and Chaldeans, since many of their ancient philosophers had relations with the Egyptians, as well as the Chaldeans.

A hundred years ago, this past into which we are trying to penetrate was indeed a sealed book. A century ago we knew nothing, for instance, of the ancient Chaldeans, save through the medium of Herodotus, Diodorus, Plato, etc. And then there existed not the slightest hope of our ever deciphering their hieroglyphics and recovering their extinct language. For fifteen centuries these hieroglyphic writings remained undeciphered and unknown; for, on the triumph of Christianity, the idolatrous religion of the ancient Chaldeans was regarded with pious abhorrence by the early Christians, and so, in the course of time, the hieroglyphics became neglected and forgotten, and their monuments—with their precious contents—were left to the destroying hand of time and the vandalism of savage tribes.

Their cuneiform inscriptions have been, until quite recently, lost to the world since the Macedonian conquest of Persia. But who can set a limit to the powers of human genius? Thanks to the discovery of the celebrated rock of Behistun, at Kermanshah in Persia — a perpendicular rock, rising abruptly 1700 feet above the plain, the lower part of which bears inscriptions for the space of about 300 feet in the three languages, Persian, Scythian, and Assyrian—which, by comparing the known with the unknown, enabled Mr (after Sir Henry) Rawlinson, a cadet, and a *ci-devant* clerk of the East India House named Norris, supplemented by the discoveries of Austen Layard (an articled clerk) and others, to recover this long lost cuneiform or wedged-shaped writing of the ancient Chaldeans.

Long before the discoveries of modern science, the people of old beheld, in the double valley of the Tigris and Euphrates the birth of their race and of their faith. It is there that imagination established the reign of gold and placed the terrestial paradise. Thither, in imagination unbiassed by prejudice, then must we wend our way, if we would become acquainted with discoveries, so far back in the past that nearly all trace of their origin is lost; yet which vie in interest and importance with the proudest achievements of any age.

But 'it is a foolish thing to make a long prologue, and to be short in the story itself,' as the author of the book of Maccabees said.

Let us, therefore, without further preface, pass on to the story itself, if we would

'. . . *Know the mystic song*
Chanted when the sphere was young.'

PART II.

THE CHALDEAN SCIENCES.

'*Babylone est une coupe d'or dans la main du Seigneur toutes les nations ont bu de son vin, et elle a enivré la terre.*'

The ancient world was filled with the learning of the ancient Chaldeans. The kings of Assyria sent their subjects to be instructed at Ur and Agade; they instructed the Ionian philosophers in astronomy in the most flourishing period of Greece, and Eudoxus and Aristotle as Babylon fell; and Ptolemy, in the second century after Christ, still had recourse to their calculations. It was to them that the Egyptians owed their knowledge of astronomy, and probably of mathematics also; for the Egyptian zodiac corresponded with the dodecatemoria of the Chaldeans, and though some of the Chaldean constellations were modified in Egyptian temples, yet there exists a sufficient general resemblance between the Egyptian arrangement, and that which other nations have derived from the Chaldeans, to show the real origin of the figures which adorn Egyptian zodiac temples.

And the argument derivable from astrology is even stronger, the whole system of astrology being so peculiar and artificial, that it must of necessity be ascribed to one nation. And the Egyptians themselves admitted the superiority of the Chaldean astrologers, and the common consent of all eastern nations accorded with this view. All that we know from Herodotus and Manethon, and all the evidence of the pyramid kings, corroborates the fact that the Egyptian astronomy (and astrology) was derived from the Chaldeans.

And another argument in favour of the Chaldean origin of astronomy and astrology is derivable from the fact that the system of astronomy taught in Egypt, Babylon, Persepolis, and elsewhere, does not correspond with the latitude of these places. This argument will be considered further on, and need not detain us here. And lastly, it is natural that astronomy, astrology, and that form of nature worship known as Sabæism, should have had their birth, or rather earlier developments, in Chaldea. The Chaldean plains, uninterrupted by a single eminence, and rarely shadowed by a passing cloud, were a fit place for the birth of astronomy, the wonderful movements of the heavenly bodies, their splendour, and even their effects upon the physical world, must have been long apparent to the Chaldean shepherds long before they became the study of the philosophers and the priests. It is no idle fancy that assigns to shepherds the *rôle* of the first astronomers. A minute study of the *débris* of the ancient Chaldean civilisation, and the translation of Assyrian and Sumero-Accadian texts, has revealed to us the existence, upon the banks of the Euphrates, of an intelligent people, desirous of knowledge, and ingenious in their speculation, persevering in their researches, and who, very anciently, endeavoured to discover the cause and origin of a phenomena daily occurring in the midst of nature before their eyes. The famous sciences of the Chaldeans, and, later, the Assyrians also, were confined chiefly to some knowledge of astronomy and mathematics, natural philosophy, and an immense medley of astrology, of magic, and (to us) childish but interesting conceptions of the origin of things.

Each Babylonian town possessed its observatory[1] and astronomer-royal, who had to send fortnightly reports to the king. The astronomers, without ceasing in their observations, carefully registered everything that passed in the heavens.

They compared their reports, for the most part written by order of the sovereign, and left under his care. Much of this has been found on the tablets discovered at Nineveh. The following is an example :—

'To the king, my lord, let the gods Nabu and Marduk be propitious, let the great gods grant to the king, my master, long days, good health, and a contented heart. On the 27th day (of the month) the moon disappeared; during the 28th day, the 29th, and the 30th, we have continually observed the node of obscuration of the sun. The eclipse did not take place. The 1st day of the following month, the month of Duzu (June), we beheld the moon journeying above the star Nabu (Mercury), concerning which I have previously sent the observation to the king, my master. In her course during the day Anu, in the vicinity of the star Berger, she was seen declining; on account of rain, the horns were not visible very clearly, and so on during the route. On the day Anu I sent to the king, my master, the observation of her conjunction. She separated herself, and was visible above the star Char in her course during the day Bel (Thursday), she has disappeared towards the star Char. To the king, my lord, peace and goodwill.'

---

[1] The observatory was a high pyramidal tower of seven stages, which generally served as a temple as well, and which adjoined the palace of the king.

Observations of this kind, patiently recorded day after day for many centuries in time of necessity, gave birth to some true ideas of the motions of the stars. What these ideas were, as far as we at present know, will be part of the subject-matter of the following pages. The subject is one of the deepest interest, for, if the classical scholars were correct in their belief that Chaldea was the birthplace of astronomy, and that their own astronomical knowledge was derived chiefly from this quarter, it must be well worth inquiry what the amount of knowledge was which the Chaldeans attained in astronomy, and the means whereby they made their discoveries.

ASTRONOMY.

'The standard work on astronomy and astrology was that in seventy-two books, compiled for the library of Sargon (3800 B.C.), at Agadé, and entitled the "Observations of Bel." It was subsequently translated into Greek by Bêrôsos. The table of contents shows that it treated of various matters—eclipses, comets, the pole-star, the phases of Venus and Mars, the conjunction of the sun and moon, the changes of the weather, and the like. After each observation comes the event which was believed to have happened in connection with it, and the number of observations shows for how long a period they must have been accumulating before the second millennium B.C. We can, in fact, trace the beginnings of Babylonian astronomy back to an age when the Accadians were still shepherds and herdsmen among the mountains of Elam (*i.e.*, Susiana or Shusan); it was above Elam that the zenith was fixed, and the heaven was regarded as a great pasture land, the ecliptic being "the bull of light," or "the furrow of the sky," and the stars "the heavenly flock," whose shepherd was Acturus (a Bootis). It may be added that Tammuz represented Orion.'[1]

And, moreover, a table of lunar longitudes has been discovered belonging to the Accadian period, and fragments of a planisphere, marking the appearance of the sky at the vernal equinox, both of which are now in the British Museum. One of the most important documents, however, that we possess concerning the astonomical knowledge of these past ages, is that contained in some Assyrian tablets lately deciphered by Mr G. Smith. These tablets are copies of some very, very old Babylonian ones, Professor Sayce and Mr Smith having traced the origin of the clay tablet literature to the Accadians, an older race than the Assyrians, the precursors of the Babylonians. This tablet, or rather the original from which it is copied, is certainly long anterior to the reign of Sargon the ancient[1] (3800 B.C.), one of the earliest Chaldean kings at present known. The account runs as follows:[2]—

---

[1] Professor Sayce.

(1.) All that was fixed by the great God was good.

(2.) He arranged the stars in figures of animals.

(3.) To fix the years through observation of their groupings.

(4.) He arranged twelve monthly in sets of three, *i.e.*, to correspond to the four seasons—three signs to a season.

(5.) From the day when the year commences unto the close.

(6.) He marked the position of the wandering stars (*i.e.*, of the planets) to shine in their paths.

(7.) That they may not injure each other or come into collision.

(8.) The position of the gods Bel (Jupiter) and Hea (Saturn) he assigned.

---

[1] This date of Sargon's is fixable from the fact that this king built a temple which was restored by Nabonid (555 B.C.), and an inscription of his states that certain inscribed cylinders buried in the foundations had not been seen for 3200 years.

[2] The reader should compare this with Genesis.

(9.) And he opened the great gates in the darkness shrouded.

(10.) The fastenings were strong on the right and left.

(11.) In its mass (*i.e.*, the lower chaos) he made a boiling.

(12.) The god Uru (the moon) he caused to rise out, and the night he overcame.

(13.) To fix it, also, for the light of the night until the rising of the day.

(14.) That the month might not be broken, and might be regular in length.

(15.) At the beginning of the month, at the rising of the night,

(16.) His horns are breaking through, to shine on the heavens.

(17.) On the seventh day, to a circle he begins to swell.

(18.) And stretches towards the dawn further.

(19.) When the god Shamas (the sun) in the horizon of heaven, in the east

Note.—Recent researches appear to show that, prior to this, eclipses had been recorded for ages. The twelve signs of the zodiac were—the Bull (with Pleiads), Ram, Twins, Crab (Scorpion), Lion (of the Sun), Virgin (Ishtar), Altar, Scorpion, Archer, Goat, Aquarius, Fishes (one for Adar and one for Ve-adar).

(20.) . . . formed beautifully . . .
(21.) . . . to its orbit Shamas was perfected. . . .

The remainder of this document of inappreciable value is unfortunately lost, though it may be hereafter recovered, as it is known several copies of this ancient work existed. Its antiquity cannot be doubted, and it is clearly anterior to the very similar account of the sun, moon, and stars given in the first chapter of Genesis, for the fact that the account in Genesis is free from polytheistic ideas proves it to be more recent than the Chaldean version, for polytheism, we know, long preceded monotheism.

This document shows us that, earlier perhaps than 4000 B.C.,

(*a*) The stars were already grouped into constellations.
(*b*) The signs of the zodiac determined,
(*c*) The planets discovered,
(*d*) Their periods of revolution and relative distances (roughly) determined. The month measured by the moon, and the year by observation of one of the constellations

(probably the Pleiades).[1] This document also tells us (15, 16, 17) that the first division of the lunar month into two halves was when the moon was half-full increasing, and half-full diminishing. After this division of the month into two halves comes the division of these two parts into two equal parts, the origin of our week of seven days.

But at this early period in man's endeavour to read the mystery of the stars, there was mingled, with real observed facts, much that is to us erroneous and fanciful. The people of this remote past, according to the ingenious representation of a Greek writer of the first century A.D., imagined the earth to have the shape of an inverted round boat or bowl, the thickness of which represented the mixture of land and water, *i.e.*, the crust of the earth, while the hollow below this inhabited crust was imagined by them to be a bottomless pit or abyss, in which dwelt many powers. Above the convex surface of the earth was spread the sky itself, divided into two regions—the firmament and highest heaven, which revolved, with the fixed stars immovably attached to it, on an axis or pivot, around an immensely high mountain, which joined it to the earth like a pillar. This mountain was supposed to be situated somewhere in the far north or north-east; and the lower heaven, where the planets—a kind of resplendent animals of beneficent nature, seven in number—wandered for ever on their appointed path. Seven was, even at that early period in man's history, a sacred and mysterious number. Such is a brief glimpse into the *most remote* past of the history of astronomy; erroneous and fanciful though some of their ideas were, what centuries of culture and progress separate *their* astronomy from that of a certain African tribe, whose opinion it was that the inhabitants of the west fried the sun when he entered into their regions, and after heating him sufficiently for the next day's service, led him round by a private passage to the east. Were it possible to collect the astronomy of the whole ancient world, there is but little doubt, I think, that the comparatively humble efforts of these old Accadians or Turanian Chaldeans would appear miracles of sense and reflection among theories not much superior to those of Mungo Park's Africans. It is of course —*as yet*—quite impossible to fix the date of, practically, *any* of the Chaldean discoveries in astronomy (or, indeed, in any science); it is only possible to give an account of the amount of astronomical knowledge possessed by the Chaldeans, founding our account on the testimony of ancient writers and modern Oriental research.

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[1] The determination of the length of the year by means of the sun's varying altitude belongs to a more recent period of astronomy.

The Babylonians recorded their observations on bricks and tiles. Many such tablets, formed of clay, and bearing inscriptions in cuneiform characters, have been discovered by Mr Layard and other eastern travellers. Many of the inscriptions appear to have no reference to astronomical observations. Across these tablets, while yet moist, engraved cylinders were rolled, the impressions appearing in general to be records of celestial phenomena. 'It may be conjectured,' says R. A. Proctor, 'that one of the duties of the Chaldeans was to superintend the construction of cylinders, the symbols on which should serve to indicate the date corresponding to each tablet.' It is perhaps most probable that only the symbols around the principal figures, and in the background, are astronomical. It has been suggested that the principal figures represent constellations. Among symbols representing the sun, moon, and stars, Dr Birch has detected figures corresponding to ten of the zodiacal constellations. However this may be, there is no doubt that the researches of scholars and travellers in the East will, ere long, discover a meaning to symbols and inscriptions at present unintelligible, enabling us thereby to become better acquainted with the methods of observation employed by the Chaldeans, with the manner in which they recorded, and of the system by which they explained astronomical phenomena. Every year, almost every month, brings to light some new discovery. Twenty-five years ago, for instance, the subject-matter of the foregoing pages was a sealed book, the religion and mythology of the old Accadians entirely unknown. Before passing on to our narration of what ancient testimony in conjunction with modern research has revealed to us about the astronomical and scientific knowledge of these ancient people, we will obtain one glimpse at ancient Chaldean astronomy through another source. The late R. A. Proctor, in his delightful work on 'the Great Pyramid,'[1] has shown that, in all probability, they who superintended its erection, as far as astronomical (and mathematical) relations were concerned, were Chaldeans; and most probably that particular branch of the Chaldean family which went out from Ur of the Chaldees because they would not worship the gods of the Chaldeans. If this be so, and all the evidence is in favour of this supposition, then, as early as 3400 B.C. (the probable date of the erection of the Great Pyramid), the Chaldeans were able—

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[1] Josephus says that the Patriarch Abraham, having learned the art (astrology) in Chaldea, when he journeyed into Egypt, taught the Egyptians the sciences of arithmetic and astrology.

Mr Petrie has pointed out that the scale marked on a plan in the lap of one of the statues from Tell-Ho (which some recent French excavations have unearthed), agrees with that used in Egypt in the age of the pyramid builders. And the pyramid of Kochome, near Sakkara, one of the earliest Egyptian monuments, is built in steps like the seven-storied Babylonian temples, and that this pyramid was also originally seven-storied has now, I believe, been placed beyond a doubt. We also now know (owing to the recent discovery of cuneiform tablets at Amarna, in Upper Egypt), that there was an active literary correspondence, from one end of the civilised East to the other, as early, at any rate, as 1703 B.C.; the medium of the correspondence was the *Babylonian* language, correctly written.

(*a*) To measure with a remarkable degree of exactness the diameter of the earth, supposing the earth a perfect globe not compressed at the poles.

(*b*) To determine, with the same degree of exactness, the *latitude* of a place.

(*c*) To orient a building with a wonderful degree of exactness, by taking the altitude of a polar star, as well as by means of the sun's varying altitude. (This gave the N. and S. line; the E. and W. line they determined by means of an empirical knowledge of Euc. I. 47.

(*d*) The simpler laws of reflection in optics were known to them, but not refraction, at any rate in its effect on the heavenly bodies. A fairly accurate approximation had also been obtained of the ratio of a diameter of a circle to its circumference, known in other words as the quadrature of the circle.

This knowledge necessitates, of course, a really advanced skill in astronomy and mathematics, an astronomy in advance of that of the Greeks in the time of Hipparchus,[1] and a knowledge of mathematics in some respects certainly advanced, but more of this latter anon.

The Chaldeans were able to foretell eclipses of the moon, and announce the days on which eclipses of the sun might be expected, by means of their period known as the Saros. This period, of course, they discovered empirically, but the wonderful accuracy with which the Chaldean astronomers had determined this famous cycle, as early as 2000 B.C., and, perhaps, two thousand years earlier, is a proof that they must have observed the heavenly bodies with the most scrupulous exactness for many centuries before they could have achieved such a success. Having arrived at the conclusion that eclipses of the moon were caused by that body entering the shadow of the earth in space, and eclipses of the sun by the interposition of the body of the moon between the sun and earth, they patiently recorded these eclipses year after year, and century after century, till it was at length observed that when these eclipses had been registered for a period of 223 lunations, or about 18 years and 11 days, and the days on which they fell recorded, then it was found that approximately, on each and every one of these days during the next same period of 223 lunations, eclipses might be expected, and their coming foretold.

---

[1] 'Greek natural philosophers,' says Humboldt, 'were but little disposed to pursue observations, but evinced inexhaustible fertility in giving the most varied interpretations of half-perceived facts.'

Note.—Amongst the constellations mapped out at even this remote period were Perseus, the Dragon, Eagle, Swan, Cepheus, Andromeda, Cassiopeia, Orion, Great Dog, Hydra, Cup, Crow, Centaur, Wolf, Southern Fish, Eridanus, and Argo. It is worthy of careful notice that the position of the ship *Argo* was *horizontal* when culminating about 3400 B.C. As a ship may be said to be in her natural position when on an even keel, we have in this result alone evidence of some force to show that this constellation received its name prior to 3000 B.C., a fact confirmed as it is by other evidence.

This remarkable fact was known to the ancient Hindus, Chaldeans, Chinese, and Egyptians (nations widely diffused), at a very remote period of antiquity, which alone shows how far back in the world's history its origin must be.

The Chaldeans foretold eclipses of the moon far more often than those of the sun, for, in effect, the *Saros* is not in itself sufficient to know for certain the latter in advance.

The five planets, Hea (Saturn),[1] Bel (Jupiter),[2] Nergal (Mars), Astarta (Venus),[3] and Nabu (Mercury),[4]—placing in the same category the sun[5] and moon,[6]—were known, as we have seen, to the ancient Chaldeans anterior to the reign of Sargon I. (3800 B.C.).

The stars they had at a very early period —as we have seen—grouped into constellations, and determined the signs and names of most of them, particularly those which

Note.—The Chaldean value of the Saros was 6585 days, 8 hours, exceeding the true period by only 19 minutes 22 seconds.—*R. A. Proctor.*

[1] Also called Nisroch and Nindar, or Ninip (originally another name for the Sun).

[2] Called also Bel-Marudak, or simply Maruduk, or Marduk; the Merodach of the Hebrews.

[3] Called also Ishtar, Mylitta, and Belit, the Ashtoreth of the Hebrews.

[4] Or Nebo.

[5] Called Shamash.

[6] Called Sin, or Uru-ki, or Namur in the old Accadian language; so Shamash is termed by them Ud, or Barbar. Among the Hebrews, Ashtoreth denoted the Moon, and not Venus, as among the Chaldeans. Baal or Moloch was the Canaanite Sun-god, as Ashtoreth was their Moon-god.

compose the zodiac. They were acquainted with the year of 365 days, 6 hours, 11 minutes, having determined the length of the year more correctly even than Hipparchus did (160-145 B.C.), though he had the immense advantage of being able to compare his own observations with those recorded by the Chaldeans. For civil purposes, however, they employed a year of a dozen lunations of the moon, which they made agree with the solar year by means of a supplementary month. They divided their lunar month of 29½ days at first into four weeks of seven days each.[1] They were the first who gave the seven days of the week the names of the seven planets, which have descended even to us.[2] The seven days in order being assigned to the planet ruling their first hour, as follows :—

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[1] And later into six periods of five days each. This double division was adopted by the Hebrews.

[2] The 7th, 14th, 19th, 21st, and 28th days of the lunar month were kept even in the Accadian times like the Jewish Sabbath derived from them, and were actually so named in Assyria. They were termed *dies nefasti* in Accadian, rendered 'days of completion (of labour)' in Assyrian; the Assyrian *Sabattu* or 'Sabbath' (derived from the Accadian *the origin of* OUR *modern Sabbath of like nature*) itself being further defined as meaning 'completion of work' and 'a day of rest for the soul.' 'On these days,' says Professor Sayce, 'it was forbidden—at all events in the Accadian period—to cook food, to change one's dress or wear white robes, to offer sacrifice, to ride in a chariot, or even to use medicine.'

(1.) The Sun's day (Sunday).
(2.) The Moon's day (Monday, Lundi).
(3.) Mars' day (Tuesday, Mardi).
(4.) Mercury's day (Wednesday, Mercredi).
(5.) Jupiter's day (Thursday, Jendi).
(6.) Venus's day (Friday, Veneris dies, Vendredi).
(7.) Saturn's day (Saturday, *Ital.*, il Sabbato).

The day they divided into 24 hours, the hour into 60 minutes, and the minute into 60 seconds, just as we do now. Besides the cycle of the Saros already spoken of, they recognised a cycle of 43,200 years, which they regarded as a single day in the existence of the universe. This cycle they divided into 12 *sares*, or hours of the world, each of 3600 years ; the sare contained 60 sosses, or cosmic minutes, each of 60 years ; and lastly, the year represented a second in the eternal order of things. 'They accomplished, moreover, a catalogue of the fixed stars, of which the Greeks made use in compiling their stellar tables. And the general laws of the movements of the heavenly bodies seem to have been so far known to them, that they were able to state by anticipation the position of the planets throughout the year.'[1]

With regard to what is known as 'the precession of the equinoxes,' there is now no doubt that they had made an empirical discovery of this fact, its explanation, of course being far beyond them. Indeed, its explanation is one of those discoveries which helped to confer immortality on the great Newton. We know now the equinoxes were early observed in Chaldea, testimony of this being furnished by inscriptions recording the dates of the equinoxes, and the discovery of a valuable tablet by Mr Rassam amid the ruins of the ancient city of Sippara of the sun, has shown, together with the discovery of a Babylonian calendar, that the periods of the equinoxes and the solstices were made the time of great religious festivals; and we also learn from the inscription that there was a time in the annals of Babylonian astronomy when the vernal and autumnal equinoxes fell

Note.—They were acquainted with the precession of the equinoxes making use of a tropical year of 365 days, 5 hours, 49 minutes, 11 seconds (only 25 seconds too great), and a sidereal year of 365 days, 6 hours, 11 minutes (not quite 2 minutes too great.)—*R. A. Proctor.*

[1] Rawlinson.

in Taurus and Scorpio. A passage in Virgil corroborates this, wherein he says :—

> '*Candidus auratis aperit cum cornibus annum*
> *Taurus* . . .'

'When the white bull opens the year with his gilded horns.' Now, as far back as 2540 B.C., the vernal equinox had fallen, or the spring had opened, with the sun in Aries, not in Taurus. Virgil's astronomy, we know, was not his own. From what source he derived it we know not, although, after the above, there remains, I think, but little doubt that it was derived originally from the Chaldeans. This discovery of the precession of the equinoxes justly ranks amongst the most important of antiquity, and to have detected the fact, and to have marked a motion so slow and hidden, gives evidence of a closeness of observation worthy of the highest admiration. Modern science has determined its rate of motion, and its vast period of nearly 26,000 years has been fixed.

It has been said by some that the Chaldeans were acquainted with the *rings of Saturn, the phases of Venus, the satellites of Jupiter, and the true, or Copernican, system of the Universe.* The ancient Chaldeans were not entirely ignorant of optics. A glass lens has, in fact, been found in the ruins of Nineveh ; and of their hieroglyphic writing a great deal is so minute that a powerful lens has to be used to decipher it. Whether their optical knowledge was sufficient for the discovery of the rings of Saturn, and Jupiter's satellites, is perhaps a doubtful question. It is, however, a very curious coincidence that the Chaldeans always represented the god or planet Saturn within a ring and triple. 'Galileo's first view of Saturn,' says R. A. Proctor, 'with feeble telescopic power, showed the planet as triple (tergiminus) ; and a very moderate optical knowledge, such as we may fairly infer from the presence of optical instruments among Assyrian remains, might have led to the discovery of Saturn's rings and Jupiter's moons. (Bel, the Assyrian Jupiter, was represented sometimes with four star-tipped wings.) But it is possible that these are mere coincidences. Saturn would naturally become to be regarded as the god of Time, on account of his slow motion round the ecliptic ; and thus the ring (a natural emblem of time) might be expected to appear in figures of the god corresponding to this planet. It is curious, however, that the ring is flat, and proportioned like Saturn's.[1] It is certainly not incredible, that mechanicians so ingenious as we know the Chaldeans to have been, and acquainted, moreover, as they were with the simpler laws of optics, should have been able to construct telescopes of sufficient power to enable them to detect the phases of Venus,[2] Jupiter's satellites, and Saturn's rings. The researches of travellers and students in the East will, no doubt, ere long bring to light further and more accurate evidence on these interesting questions.

Passing on now as to whether the Chaldeans were acquainted with the true or Copernican system of the universe: 'There are,' says R. A. Proctor (Appendix A, 'Saturn and its System,' pp. 192-193), 'good reasons for supposing that the Chaldeans were acquainted with the true system of the universe. The ancients were acquainted with the relative distances of the planets, a knowledge which could only have been obtained from considerations founded on a true system.' Further on he adds, 'It appears, indeed, highly probable that their observations were conducted with sufficient accuracy to enable them to detect the ellipticity of the planetary orbits. The account given by Philolaus of the opinion of Pythagoras, seems clearly to point to knowledge of this kind.

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[1] *Vide* also Appendix A to Proctor's 'Saturn and its System,' pp. 195-199, for further evidence on this point.

[2] At all events, one astronomical record states that 'Venus rises, and in its orbit duly grows in size.'

There is no evidence that the Chaldean astronomers were acquainted with the nature of *gravity.* The idea was, perhaps, conceived by them of the sun and planets exercising some attractive influence, varying with their distance and volume, but there is no reason to suppose that they were able to deduce from the motions of the planets the manner in which such attraction varied, still less that the general principle of universal gravitation was known to them.

They appear to have advanced the correct theory, that *comets* are bodies travelling in

Note.—The reader desiring fuller information on 'The Astronomy and Astrology of the Babylonians,' should read Prof. Sayce's Paper on the subject in the 'Transactions of the Society of Biblical Archæology' (Vol. III. part i. 1874), Appendix A to Proctor's 'Saturn and its System,' and Sir G. C. Lewis's 'Astronomy of the Ancients,' a work valuable for its materials, though not for its conclusion.

extended orbits, and a conjecture made (founded on certain passages in Apollonius Myndius and Diodorus) that they were able to predict their return. The passage in Apollonius Myndius I have not met with. In those passages in Diodorus, where he speaks of the ancient Chaldeans, I have not found any direct allusion to the prediction of the return of comets. In a passage where he is speaking of the state of the mathematical, astronomical, and astrological knowledge of the ancient Egyptians, the following occurs:—'In predicting to men the future, these astrologers often foretell correctly; they predict dearth as frequently as plenty; epidemics and diseases of the flocks. Earthquakes, inundations, the apparition of comets, and many other phenomena which the unlearned are not able to learn in advance, they predict, after observations continued for a long space of time.' Though this is probably an exaggeration, it must be borne in mind that, close observers of nature as they were, and devoting as they did their whole time to watch her operations, they were able to note and record warning signs, with regard to earthquakes, etc., that escaped the notice of the less observant. Such being the case, it is, of course, not incredible that they may empirically have determined the periods of revolution of some comets. 'Callisthenes,' says Porphyrius, 'sent to Greece observations of the planetary motions taken by the Chaldeans for 1903 years before Alexander's entry into Babylon.'

The most marvellous discovery of the ancient Chaldeans was undoubtedly the prediction of an eclipse. That by careful observation, extending over many, many centuries, they should have come to the conclusion that an eclipse of the moon was caused by that body entering the shadow of the earth in space, and an eclipse of the sun by the interposition, between the earth and sun, of the dark body of the moon; or even prior to this, that moonlight was but reflected sunlight, are, in themselves, discoveries sufficiently remarkable; but to be able to stretch forward in time, and anticipate, and predict the coming of these dread phenomena! How wonderful and how mysterious! The prediction of an eclipse, a phenomena, which, even now, when its most minute phenomena are foretold with the most rigorous exactitude, cannot be witnessed without a feeling of involuntary dismay. What, then, must have been its effects upon the human mind, when its cause was unknown, and when these terrific phenomena burst on the earth's inhabitants, unheralded and unannounced? An investigation into the laws that governed them was one not prompted by curiosity alone, but involving the peace and security of man in all coming ages. With what derision must the first predictor's announcement have been received. But his triumph; can you point to a greater? While an agony of despair dashed stricken millions to the earth, his heart alone was filled with triumphant victory. 'Search,' said a writer, 'the records of our race, and point me, if you can, a scene more grand, more beautiful. It was the proudest victory that genius ever won. It was the conquering of ignorance, of superstition, of terror, all at a single blow, and that blow struck (probably) by a single arm.' Do you demand his name? It has perished; age, name, nation, country, all have been swept into oblivion. He who must have been regarded by his countrymen as little less than a god, 'even this one too has perished from the earth.' But *we* have inherited the fruits of his victory, and can honour his *unknown* name, even as we honour the names of Copernicus, of Galileo, and of Kepler.

ASTRONOMICAL INSTRUMENTS.

Amongst the instruments which they used in astronomy was the *Gnomon*, originally a straight rod placed vertically upright on a smooth or level piece of ground; a simple instrument, truly, and yet one which, by carefully observing the noon shadows cast by the sun, enabled those early astronomers to determine, with a considerable degree of accuracy, the four cardinal points, the true mid-day, the epochs of the solstices and equinoxes, the obliquity of the ecliptic, the latitude of place, etc.[1] In later times three concentric circles were drawn on the plane in which the rod was placed, so that, at the summer solstice, its shadow just reached the inner circle; at the equinoxes, the middle; and at the winter solstice, the outer. Afterwards, in places in which the latitude was known, the circles were omitted, and three spots or dots, marked on the meridian line, were substituted.

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[1] *Vide* any popular work on astronomy.

The *Polos*, or sun-dial, originally an upright stick placed in a graduated bowl, and in later times a staff placed in the centre of six concentric circles, so that every two hours the shadow of the staff passed from one circle to another. They also used various kinds of *Astrolabes* (from two Greek words signifying 'to take the stars'), a name given by the Greeks to any *circular* instrument for observing the altitude, etc., of the stars. Circular rings, arranged as in the armillary sphere, were used for this purpose, and a projection of the sphere upon a plane, with a graduated rim and sights for taking altitudes, was known as an astrolabe in the palmy days of astrology, and was the badge of the astrologer. The best kind of astrolabe known to the Chaldeans appears to have been a rather rough kind of armillary sphere.

The Planisphere (the name given for any representation of all or part of a sphere on a plane) was also known to them ; fragments of various planispheres having been discovered amongst the ruins. The *clepsedra*, or water-clock, was of Chaldean invention, and such devices and instruments as Ferguson, the self-taught Scotch peasant-astronomer, employed to determine the position of the stars, would be likely to occur to the ancient Chaldeans.

OBSERVATORIES.[1]

Their observatories, or 'ziggurats' (*i.e.*, 'mountain peak') were high pyramidal towers of three, five, or seven stages, always one of the three sacred numbers, three corresponding to the divine Triad; five to the five planets; seven to the sun, planets, and moon. In later times, however, the number of stages was generally, if not always, seven. The seven stages represented the seven spheres, in which moved, according to ancient Chaldean astronomy, the seven planets; to each planet, fancy, grounded partly on fact, assigned a particular colour or hue. Each stage was assigned to a particular planet, the basement stage, black, to Saturn ; the second stage, orange, to Jupiter ; the third, blood-red, to Mars ; the fourth, golden, to the Sun ; the fifth, yellow, to Venus ; the sixth, azure, to Mercury ; the seventh, silver, to the Moon. They were oriented with a remarkable degree of exactness, their *corners* pointing exactly to the four cardinal points—north, south, east, and west. Only two exceptions have been found to this rule, one in Babylon (the temple of Bel), and the Assyrian ziggurat at Nimrud, explored by Layard, of which the *sides* (as in Egypt), and not the corners, face the cardinal points. This singular orientation had long been a puzzle which no astronomical calculations were able to solve. Quite lately, however (1883), Mr Pinches found a small tablet, containing, amongst other things, the following brief geographical notice, in illustration of the position assigned to the cardinal points :—' The South is Elam, the North is Accad, the East is Suedin and Gutium, the West is Phœnicia. On the right is Accad, on the left is Elam, in front is Phœnicia, behind are Suedin and Gutium.' Now, examining an ancient map, we at once see that the direction given by the tablet to the *South* (Elam) corresponds to our *South-East;* that given to the *North* (Accad) to our *North-West;* while *West* (Phœnicia, *i.e.*, the coast line of the Mediterranean, down almost to Egypt) to our *South-West*, and *East* (Gutium, the highlands of Armenia, now the Kurdish Mountains) to our *North-East.* If we turn the map so that Babylon comes in a perpendicular line above the Persian Gulf, the desired effect is produced, and it becomes apparent that the Chaldean ziggurats *did* face the cardinal points, according to their geography, *with their sides;* and that the decipherment of this small tablet settles the difficult question of the difference in orientation between Assyrian and Egyptian monuments. It has been suggested that these two different systems of orientation originated no doubt from two different races, 'and that their determination was due probably *to the geographical position of the primitive home of each race.* Now, the south-west in this tablet of unappreciable value is called 'the front,' and therefore the migrations of this people must have been from north-east to south-west. This, of course, singularly tallies with the hypothesis that the primitive or semi-primitive home of this people was among the mountains of Armenia, or the Altai Mountains of Central Asia, of which more anon.

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[1] I do not include these under the head of astronomical instruments, because we do not know that these Chaldean towers were pierced with passages for the observation of the stars, like those of Gizeh.

MATHEMATICS.

Turning now to the mathematical knowledge of the ancient Chaldeans, their knowledge of this science was, if anything, more remarkable than their knowledge of astronomy, the science of numbers amongst this ancient people comparing, in some respects, favourably with our own. 'The attention given to astronomy,' says Professor Sayce, 'presupposes a considerable advance in mathematics. This, in fact, was the case. The system of ciphers was a comparatively easy one to handle, and was simplified by the habit of understanding the multiple 60 in expressing high numbers,—IV., for instance, denoting $4 \times 60 = 240$. Sixty was also the

Note.—The great ziggurat of the seven spheres at Borsip *faced* the north-east with its front. This may have some connection with the sacredness ascribed to that region as the original home of the race, and the seat of that sacred mountain so often described as 'The Great Mountain of Countries,' doubly sacred as the meeting-place of the gods, and the place of entrance to the 'Arallu' or Lower World.

unexpressed denominator of a fraction, $1\frac{2}{3}$ being represented by I, XL., *i.e.*, $1\frac{40}{60}$. A tablet from the library of Lása gives a table of squares and cubes correctly calculated from 1 to 60; and a series of geometrical figures, used for augural purposes, implies the existence of a Babylonian Euclid.'[1]

Quite recently an Egyptian hieratic papyrus, included in the Rhind collection of the British Museum, has been deciphered, and found to be a mathematical handbook, containing problems in arithmetic and geometry. The book was written by one Ahmes (Aahmesu—moon-born), in the reign of Ra-ā-us (Apepa or Apophis of the Hyksos XVIth or XVIIth dynasty), some time before 1780 B.C., but it was founded on and follows, *not always correctly* (the italics are our own), an older work. It is entitled, 'Directions for obtaining the knowledge of all dark things;' but it contains, in fact, hardly any general rules of procedure, but chiefly mere statements of results, intended, possibly, to be explained by a teacher to his pupil. Dr

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[1] 'The plan of an estate outside the gate of Zamama at Babylon, in the time of Nebuchadnezzar (1150 B.C.), has been discovered, which shows no mean knowledge of surveying.'—*Professor Sayce.*

Birch has traced the *original*, from which this is copied, to the date 3400 B.C., the latter being written in the reign of a king whose name is not legible in Ahmes' papyrus.

Now, it would appear from this account that the Egyptian of 1700 B.C. knew less of mathematics than the Egyptian of 3400 B.C., and further, some inscriptions of the temple of Horus at Edfu, in Upper Egypt, have been deciphered, and they would appear to show that the Egyptian of 100 B.C. knew less than the Egyptian of the time of Ahmes. The inscriptions describe the lands which formed the endowment of the priestly college attached to the temple; they were given by Ptolemy XI. (107-88 B.C.); but the geometrical description of them, says a writer, made 200 years since Euclid died, is unworthy of Ahmes himself. Again, the date 3400 B.C. is the date (about) of the building of the Pyramids, to which reference has been already made, and the time about which the Chaldeans were making frequent incursions into Egypt; and thus it is, at

Note.—This papyrus, with the exception of an older leather-roll, apparently too stiff to be opened, is the only treatise on Mathematics that Egypt has left us.

any rate, not improbable that this Egyptian mathematical knowledge was of Chaldean origin; however this may be, we may certainly assume that the Chaldeans were quite as advanced (in all probability very much more so) in this science as the Egyptians; and in place of any important Chaldean remains on the subject, supply this link in the chain of the past by means of this 'Hieratic Egyptian Papyrus.'

This tells us, then, that as early as 3400 B.C. the Chaldeans were acquainted with—

(*a*) The simple rules of *Arithmetic*, and had already made some advance in the first and greatest stumbling block to calculators—the treatment of fractions.

(*b*) The *solution of simple equations* in Algebra. They (*i.e.*, some of them) being solved by the method of a *falsa positio*, or tentative assumption, so much employed by later mathematicians. Their knowledge of this science, including as well arithmetical series, harmonical, at any rate, in later times, and geometrical also; the latter, however, confined to the fact of one single example.

(*c*) A practical or empirical knowledge of a great number of propositions in elementary *Geometry*, enabling them, amongst other things, to measure the heights of inaccessible buildings and objects (Euc. I. 26, and VI. 4), determine the areas and volumes, with a fair degree of exactness of the more elementary forms, the square and oblong correctly, the isosceles triangle and isosceles parallel-trapezium incorrectly,[1] and the area of the circle by deducting from the diameter $\frac{1}{9}$ of its length, and squaring the remainder. A very fair approximation only π being taken as 3·1604. . . .

(*d*) A rudimentary knowledge of Trigonometry,[2] enabling them to measure certain angles, these angles being, by the way, most of them, the same as the corner angles of the pyramids. A coincidence worthy of notice.

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[1] 20 instead of 19·6 and 100 instead of 99·875.

[2] See J. Gow's 'Short History of Greek Mathematics.'

Note.—It may be noted that Ahmes does not give the figures to all his calculations (his determination of volumes, for instance), and gives, moreover, solutions and figures having no connection whatever with the problems to which they are appended. Without doubt those (Chaldeans ?) from whom Ahmes copied knew far more concerning mathematics than Ahmes himself did.

Thus far, at any rate, had the Chaldeans progressed in the science of mathematics at so remote a date as 3400 B.C. And crude and imperfect as their knowledge appears to us, what ages of culture and progress must have separated their arithmetic from that of many existing savages, who cannot count beyond 5; and their geometry from the time when distances were measured by 'a stone's throw,' or 'a day's journey,' and large areas and volumes by reference to labour: a field, for instance, being 'a morning's work.'[1] In later times, their knowledge of mathematics was, in all probability, very much more advanced, and it is quite possible that the Greeks were much more indebted to them than is commonly supposed.[2]

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[1] Small volumes being probably described by weight.

[2] Hankel (*Zur Gesch. der Math.*, p. 157) says,—'Of the performance of the Greeks in arithmetic, our judgment may be stated shortly thus: they are in form and contents unimportant, childish, even; and yet they are not the first steps which science takes, as yet ignorant of her aim, tottering upon shaky ground. . . . It is dotage without a future which wearies us in these writings.'

A very ancient mathematical tablet, found at Senkereh, and now in the British Museum, possesses on one side the cubes of the numbers from 1 to 60 — the numbers are accurate throughout—and on the other side a complete series of measures of length. The ancient Chaldeans employed *two*, or even *three*, systems of notation, the decimal system arising out of the habit of counting by means of the ten fingers; the *duodecimal* system, acknowledged as more convenient, on account of the number of sub-multiples of twelve, and the *sexagesimal*, which has as a base or radix the number sixty, divisible by ten and twelve, uniting, therefore, the advantages of the other two. Every one has, in the course of time, used these various methods, of which there is but little doubt, I think, that the Chaldeans[1] were the first inventors.

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[1] *i.e.*, The Turanean Chaldeans, or Accadians, the precursors of the Chaldeans. All Turanean races have this peculiarity—worthy of careful note—that they do not care for the decimal system of arithmetic, but count by dozens and sixties, referring numbers divisible by 12 and 60. This was probably the origin of the division in Babylonia of the sun's course into 360 equal parts or degrees, and of the day into twelve '*kashus*,' or double hours. The natural division of the year into twelve months made, of course, this 'sexagesimal' system of calculation very convenient, and it was applied to everything—measures of weight, distance, size, and capacity, as well as time.

The sexagesimal method is familiar to us in connection with the divisions of the circle, and the current method of reckoning time. In their calculations, the Chaldean savants employed the sexagesimal method. The circle was divided by them into 360 equal parts, called *degrees*, the degree into 60 equal parts, called *minutes*, the minute into 60 equal parts, called *seconds*, and the second into 60 equal parts, called *tierces*, or *thirds*. Their system of weights and measures they also derived, like us, from a typical unit of length. This unit was the *empan*, equivalent to about 27 millimètres, or 1 foot. Surface or square measures were given by the squares of the multiples and sub-multiples of the empan. Babylonian measures of capacity and measures of weight have also been found; the former in vases of clay, the latter in bronze of divers forms, representing lions, wild bears, ducks, and bearing an inscription of their value, together with the name of the reigning king, and that of the examiner. The unit of weight most used was the *mina*, equivalent to 497·6 grammes. Its multiple and sub-multiple were the talent and drachma.

The Greek weights and measures (the origin of our own) were derived from these same Babylonian measures, and they are said, on the authority of Aristoxenus, to have been introduced into Greece by Pythagoras himself. He is also, on the authority of Iamblichus, said to have introduced a fourth, or *musical* proportion, into Greece from Babylon, composed between numbers and their arithmetical and harmonical means. The ancient Chaldeans were, perhaps, more advanced in these sciences than is commonly supposed.

'Much of the trigonometry and spherical geometry,' says Mr Gow, 'of the later Greeks may also have been directly derived from Babylonian sources;' and Strabo says the Greek geometers often quoted the works of certain Chaldeans, as Ciden, Naburianus, and Suddenus. And in the library of Asshur-bani-pal were several treatises on arithmetic, among the fragments of which seem to be those of a multiplication table, like that which has become famous under the name of Pythagoras. In astronomy, we now know, the Chaldeans were far in advance of the Greeks, even in the time of Hipparchus (130 B.C.). And it must be remembered that, however scarce geometrical *theories* may have been in Chaldea, a very great variety of geometrical figures were used by them for mural decorations, and many other ornamental purposes. To a Greek, therefore, having acquired a taste for geometry, a visit to Chaldea would reveal a hundred geometrical constructions, which, on inspection, would suggest new theorems, and invite scientific inquiry. Empirically we know their knowledge must have been very advanced, indeed, for them to have made their discoveries in astronomy.

I may here add, that it is now generally supposed that our present arithmetical symbols were invented by some unknown Hindu. There is no evidence that the Greeks used them. The Chaldean numerals were expressed by various combinations of the wedge, evidently originally formed, like the Egyptian by combinations of the straight line, the wedge or sometimes hammer-headed appearance that this writing usually assumes evidently being a later production. There were, at the same time, numbers for the cursive as well as the cuneiform writing.

Layard found, on some painted bricks at Nimroud, some cursive numerals. The close resemblance between some of them and our present 7, 6, 4, 9, is very striking. Perhaps, after all, our present arithmetical symbolism is of Chaldean origin. However this may be, Chaldean (and Egyptian) mathematics, such as they were, were eagerly studied by the early Greek philosophers, and were the germs from which in their hands grew that magnificent science of geometry, to which every Englishmen is indebted for his first lessons in right seeing and thinking.

NATURAL PHILOSOPHY.

It is in this country, too, that we discern the birth of natural philosophy, under the auspices chiefly of mechanics, that science which has sunk deeper into the secrets of nature than any other, and towards which all other sciences are gravitating. From a period anterior to all history, this nation must have possessed mechanical contrivances for removing large masses of stone, as is proved by the blocks used in the monuments of this country. What these means were in detail, we do not know, but it is not too much, I think, to assume with Layard, that they must have been acquainted with mechanical contrivances, which are either unknown to us, or looked upon as modern inventions. 'Amongst the sculpture of Khorsabad was,' says Layard, 'I think, a bas-relief representing the moving of a block of stone, placed on a cart drawn by men.' On the most ancient bas-reliefs are representations of war-chariots, testudos, and battering rams, well adapted for the purpose for which they were used. Layard found on a bas-relief, taken from the most ancient palace of Nimroud, a representation of a *pulley*.[1] The hanging gardens of Nebuchadnezzer (1150 B.C.) are said to have been supplied with water by means of a *screw*, working on the principle of Archimedes (Strabo). 'More probable it is, however,' says Rawlinson, 'that the water was raised by means of buckets and pulleys.' The gates of Babylon are said (on the authority of Diodorus) to have been opened by means of a *machine*. Herodotus, speaking of ancient Babylon says, 'The river does not, as in Egypt, overflow the corn lands of its own accord, but is spread over them by the hand, or *by the help of engines.*' And Mr Rassam has discovered, on the site of Babylon, the remains of some hydraulic machinery used for watering the hanging gardens of Nebuchadnezzer. In these hydraulic machines, used in both Chaldea and Egypt for the irrigation of the land, we recognise the origin of the practical science of hydrostatics, the foundation stone of the theoretical science of the same name.

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[1] This pulley is precisely similar in form to those now in use.

The lever, or, to speak more correctly, the balance, existed amongst the ancient Egyptians as early as the commencement of the Middle Empire (3064 B.C.), and very likely much earlier. It was, of course, at first of rude construction; in course of time it was more and more delicately made, the last models resembling our own in beam, platform, and pillar, and that the balance was known to the Chaldeans, we learn from the following statement of Isaiah,—'They (*i.e.*, the Chaldeans) lavish gold out of the bag, and weigh silver in the *balance.*'

They possessed also some knowledge of *Optics*, for a glass lens has been found in the ruins of Nineveh. Sir David Brewster, speaking of this lens, says:—'The convex side is tolerably well polished, and though uneven from the mode in which it has been ground, it gives a tolerably distinct focus, at the distance of 4½ inches from the plane side.' He adds: 'It could not have been intended as an ornament; we are entitled, therefore, to consider it as intended to be used as a lens, either for magnifying or for concentrating the rays of the sun.'

Of their hieroglyphic writing, a great deal is so small that a powerful lens has to be used to decipher it. What their optical knowledge was in detail we do not know; there is evidence, however, that they were, as early as 3340 B.C. (the time of the building of the Great Pyramid),[1] acquainted with the simplest laws of reflection, and also, perhaps, refraction. There is also some evidence, as we have seen, that the telescope was not entirely unknown to them. With the effect of refraction upon the heavenly bodies, they do not appear to have been acquainted. The first to notice this appears to have been the famous Ptolemy of the Alexandrian school.

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[1] *See* Proctor's 'Great Pyramid.'

The origin of *Electricity*, or the first discovery made in that science—the science *par excellence* of to-day—is usually attributed to Thales, who observed the property by which yellow amber, on being subject to friction, attracts light bodies. But the Phœnicians, we know, centuries previous to the time of Thales, traded in this substance, and also in *silk*, and it would not, I think, be too much to assume, that some Phœnician, or Chaldean, or Egyptian, with whom they traded, had observed the fact that amber, being rubbed with a piece of silk, generated what we now know to be electricity, long anterior to the epoch of Thales.

ENGINEERING.

From the most remote times, the Chaldeans were great engineers. 'The whole of Babylonia,' says Herodotus, 'is like Egypt, intersected with canals. The largest of them, which runs towards the winter sun, is carried from the Euphrates into another stream called the Tigris.' According to

Diodorus, there was a tunnel under the Euphrates, which was, moreover, *vaulted.* It was cased on both sides, *i.e.*, the bricks were covered with bitumen; the walls were 4 cubits thick. The width of the passage was 15 feet, and the walls were 12 feet high to the spring of the vault. Indeed, if such a work existed, there is no reason why it should not have been vaulted. Layard found a small vaulted chamber of burnt bricks at Nimrod, but not, it is true, any traces of a vault or arch on a large scale. Arched gateways are, however, continually represented in bas-reliefs; and the rooms in the temple of Belus were, according to some, arched and supported by columns.

Mr W. M. Flinders Petrie has indubitably proved[1] that the builders of the pyramids (who, as we have already stated, were probably Chaldeans) were acquainted with tools which are regarded as among the most recent triumphs of modern invention. Their pivot-holes of the temple doors were clearly made with 'tubular' drills, made probably of bronze, the cutting-edge being set with hard jewels, probably corundum; stone coffins

[1] *Vide Engineering*, 22d June 1883.

were hollowed out by a similar method. Mr Petrie has also shown that these ancient workmen were acquainted with the use of circular cutters or saws, the cutting-edge being set with gems, like the drills for slicing hard stone, fragments exhibiting well-marked circular scorings having been found. With regard to the manufacture of stone bowls, Mr Petrie's researches seem to show that the early Egyptian (or Chaldean) turner was acquainted with the use of mechanical 'rests' for holding the turning tool. These contrivances were usually supposed to be not older than the end of the last century. The subject is of too technical a nature for those unacquainted with workshop manipulation to be pursued further; but what a light do these discoveries throw upon the civilisation of the past, a remarkable corroboration of the fact 'that nothing surpasses in modern engineering the pyramids of Ghizeh, built more than 5000 years ago.'

CHEMISTRY AND METALLURGY.

Of *Chemistry*, I think, in the modern sense of the word, the ancient Chaldeans could perforce know nothing, since it was not until the

4th of August 1774, A.D., that Priestley discovered the existence of oxygen gas, the most abundant elementary substance in nature, and the most important to living beings, and that with which the study of chemistry is best begun. A most extraordinary system of chemistry it must have been, then, amongst any nation prior to this date, since it ignored the existence of this all-pervading element. With some of the industrial proceeds of chemistry, such as metallurgy, the fabrication of colours, dyeing, etc., the ancient Chaldeans were, however, well acquainted. From the most remote antiquity, the Chaldeans knew how to work in gold, silver, copper, and bronze, and also, in all probability, in iron and tempered steel.

The fabrication of glass was also known to this nation at a period anterior to all history, and by colouring this substance by means of metallic oxides, they were enabled to manufacture artificial diamonds, rubies, emeralds, etc., with so much skill as to deceive even the eye of a *connoisseur.* They imitated pearls, also, equally well. They manufactured enamel in colours unalterable, and they appear to have known the art of fixing colours by means of mordants. Of all the nations of antiquity, the Chaldeans were, we know, the most celebrated for the weaving of cloth of divers colours. The invention of cotton-weaving is attributed by Pliny to the Babylonians. Their carpets were also most renowned. 'She saw,' said the prophet Ezekiel (xxiii. 14, 15), 'men portrayed on the walls, the images of the Chaldeans portrayed with vermilion. Girded with a girdle upon their loins, all of them princes to look to, after the manner of the Babylonians of Chaldea, the land of their nativity.'

Their seven-storied pyramidal astronomical towers they made each stage a different colour. They attributed the seven metals to the seven planets, as follows:—

> SOL *gold is, and* LUNA *silver, we threpe;*
> MARS *iron, quicksilver* MERCURY, *we clepe;*
> SATURNUS *lead, and* JUPITER *is tin;*
> *And* VENUS *copper, by my faderkin.*[1]

Every branch of metallurgy flourished

Note.—It is noteworthy that in Numbers xxxi. 22, 23, where six out of seven metals, corresponding to the seven planets of the ancients, are mentioned, we have, after gold and silver, which are naturally put first, the remaining four in the order of the distances of the corresponding planets, viz.:—brass, iron, tin, lead.

[1] Chaucer.

upon the banks of the Tigris and Euphrates. No *coins* have, however, been found either in ancient Egyptian or Chaldean ruins. Herodotus says that the Lydians were the first people who coined money. In the Bible, money is always passed by weight.

PRINTING AND SHIPBUILDING.

In those engraved cylinders used for the record of celestial phenomona, we behold the origin of engraving. And the bricks used in the building of ancient Babylon present specimens of a kind of printing in a hollow form of type. The ancient Chaldeans were great voyagers, and probably the first persons to build ships. Isaiah (xliii. 14) says: 'Thus saith the Lord your Redeemer, the Holy One of Israel: For your sake I have sent to Babylon, and have brought down all the nobles, *and the Chaldeans, whose cry is in the ships.*'

MEDICINE.

The art of medicine amongst the ancient Chaldeans appears to have been composed only of a medley of insignificent receipts and magical formulæ. Diseases being conceived as personal demons, who entered a man's body of their own accord, or under compulsion from powerful sorcerers, and illness being consequently considered as a kind of possession, clearly the only thing to do was to drive out the demon or break the spell with the aid of the beneficent Ea and his son. If this intervention was of no avail, nothing remained for the patient but to get well as he could, or to die. This is why there never was a science of medicine, in the proper sense of the word, in Chaldea, even as late as 300 or 400 B.C.

BOTANY, ZOOLOGY, GEOGRAPHY, ETC.

The library of Assur-bani-pal (664 B.C.) has revealed to us the facts of some attempts at a botanical and zoological classification. They divided the animals into families; the carnivorous, which included several species, the lion, the wolf, the dog; the canine race being divided into several different species; the herbivorous, the ox, the sheep, the goat, forming another family. The insects were classed after the manner of life; there were those who attacked wood, wool, the parasites of men and animals, etc.

Vegetables and minerals were catalogued according to their uses and resemblance.

Some geographical works, consisting of the enumeration of known towns, the names being accompanied by a list of the productions of the surrounding country, have been discovered. 'Geography found a place,' says George Smith, 'amongst the sciences, and was represented by lists of countries, towns, rivers, and mountains, notices of position, products, and character of districts, etc., etc.

The same authority states: 'There were (in Chaldea) tablets giving accounts of the law and legal decisions, and tablets with contracts, loans, deeds of sale and barter, etc.'[1]

Erroneous and fanciful as much of this knowledge was, we cannot behold a people endeavouring, so far back in the past, to take the first steps in these sciences without feelings of the profoundest respect and admiration. Their motto was the same as ours is, 'Savoir' (to know); and the same desire that led them to attempt the unravelment of that stupendous mystery by which they were (and we are) surrounded, has also tempted the modern scholar to search with such eagerness in the dust of the desert, for that *débris* which contained the thoughts—erroneous and simple though they sometimes be—of these long lost ages. Instead of smiling at their errors, let us thank them for the treasure they have left us, and see that we do our work as well for the coming generations as they endeavoured to do theirs.

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[1] A curious relic of about fifty centuries ago has just been unearthed at Kahun, in the shape of an Egyptian will. It is said to be so modern in form that it might pass muster in our Probate Court of to-day. This interesting last testament consists in a settlement by one Sekhewian of all his property and goods in favour of his brother, a priest of Osiris, and another document in favour of his wife, Teta. The discovery of such a legal instrument shows to what an extent in the east civilisation had grown nearly 3000 years before the birth of Christ. The will is also valuable as proving that, among the early Egyptians, women had the right of holding property in their own name.

Their knowledge of the sciences was, as far as we know, almost entirely practical, it is true, and obtained by empirical means; but practice and empirical knowledge must be first cultivated, to render theory and scientific knowledge possible. Theory is only the accumulation of all practice. Scientific knowledge is empirical knowledge such as is at once full, precise, and free from unconscious error; it is, in other words, perfected empirical knowledge.

In concluding this brief account of the scientific knowledge of the ancient Chaldeans, we cannot omit to call the reader's attention to the *antiquity* of science among this extraordinary people. ALL the scientific knowledge that we know these ancient Chaldeans to have possessed, appears to have been known to them as early as 3000 B.C., and the greater part of it perhaps one thousand years anterior to this. Modern pre-historic research has fully confirmed this. Thus, although we may have gone back five or six thousand years, we have arrived by no means at the origin of science. 'We have only arrived,' as Baron Bunsen said, 'at the half-way house.' Go back as far as you may in the history of the ancient Chaldeans, they still appear a people far advanced in civilisation.

Before the Assyrian period, the ancient Chaldeans, *i.e.*, more strictly speaking, the 'Turanian' Chaldeans, had composed works on history, science, and religion; and even fables and pure legends, possessing as they did, in the time of Sargon the ancient, libraries, schools, and famous tablets or books. We know that the ancient Sumero - Accadian language of the ancient Chaldeans was held in the greatest reverence by the Assyrians; they were commented on and translated by the Ninevite *savants*, just the same as we do the works of the Greeks and Romans; grammars, dictionaries, vocabularies being composed by these *savants* for the study of this dead language.

In the Accadian *legend* preserved in the library of Cuthah, an early cosmogonic system has been found. According to this, the present regulated universe was preceded by an anarchical chaos, in which Nature made its first attempts at creation. Composite creatures had been formed out of the earth and the deep like those engraved on the gems and cylinders, or painted, according to Berosus, on the walls of the temple of Bel. There were men with birds' bodies or the tails of fishes, and human beings with birds' faces. 'The philosophy of Anaximander,' says Professor Sayce, 'which has been termed an anticipation of Darwinism, may be traced to this cosmological theory.' Thus is the past connected with the present. 'With this race' (*i.e.*, the Accads), says Sir Henry Rawlinson, 'originated the art of writing, the building of cities, the institution of a religious system, and the cultivation of all science.' The questions which will naturally arise in the mind of the reader are,—*Whence* came these Accadians, who brought into the land of Chaldea the very first, and, therefore, the most essential, elements of civilisation? *Who* were they? To what *race* did they belong? Questions ten or twenty years ago admitting of no satisfactory answer whatever. Now there are grounds, however, for concluding that they (*i.e.*, the Accadians,[1] or Turanian Chaldeans) came from the neighbouring mountainous country of Armenia, or, perhaps, more probably Shushan (Susiana), whose population was Turanian. Even this country must have been only a station in this race's migration from a more northern centre. Their written language, even after they had lived for many centuries in an almost tropical country, where palms grew and lions abounded, contained no sign to designate either the one or the other. With the signs of metals—of which there are, of course, no vestiges in Chaldea — their language was, however, well stocked. 'As the Altai range, the great Siberian chain,' says a writer, 'has always been famous for its rich mines of every possible metal ore, and as the valleys of Altai are known to be the nests from which innumerable Turanian tribes scattered to the north and south, and in which many dwell to this day, after their own nomadic fashion, there is no extravagance in supposing that *there* may have been our Accads' original departure.'

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[1] 'Accad' means 'mountains' or 'highlands.'

As to what *race* these old Accadians originally belonged, it was to the Mongolian or Turanian race, for their language was of that peculiar and primitive type, partly monosyllables, partly words, rudely pieced together, which is the great characteristic of the Turanian or yellow race, and which is known in science by the general name of *agglutinative*, *i.e.*, 'glued or stuck together without change in the words, either by declension or conjugation.' Therefore *did* science and the work of civilisation begin amongst these old Accadians, it is to the Mongolian or yellow race that we are indebted for the very first elements of our civilisation; a theory which, however novel it may appear at first sight, has been hazarded by men of great genius, and which is not without testimony in its favour. For there *is* a race which we find everywhere at the very roots of history, so that not only does ancient tradition call them 'the oldest of men,' but modern science inclines more and more to the same opinion. We may, if we choose, regard Adam before the fall as typifying savage man, living simply on the fruits of Nature's garden; while after the fall he typified man living alike on the fruits of the earth and on his fellow animals. Abel, the next man, may in like manner be regarded as typifying pastoral races, and Cain, the third, as typifying races which lived later by agriculture, from whom descended fresh pastoral races of the nomadic sort, and later (by union with other races), artificers and artisans, as well as races possessing artistic and scientific skill. Why (Genesis IV. 19-20) do we never hear any more of the so-called descendants of Cain, severed in the very beginning, according to Genesis, from the rest of humanity? The writer of Genesis tells us that they lived in the 'Land of Exile,' and multiplied, and then ignores them. And, indeed, who should they be but that most ancient race, set apart by its colour and many striking peculiarities, which everywhere preceded their white brethren, but which were invariably at once supplanted by them whenever the two came into collision? It is worthy of notice, too, that of the two brothers, Cain and Abel, Cain is the oldest, which tallies admirably with the antiquity of the yellow race; and it is by no means true that the yellow race was always devoid of fine faculties or inventive genius. Quite the contrary; for, if white races everywhere stepped in, and took the work of civilisation out of their hands, and carried it on *to a perfection of which they were incapable*, still it was they, the Turanians, who had everywhere *begun* that work; it was their inventions which the others took up and improved; and it must be remembered that it is much easier to improve than invent. There both is and was, however, a curious and striking limitation to their power of progress. Consider, for example, the most brilliant example of their race—the Chinese. We owe pro-

Note.—Speaking of the genealogies of chap. X. in Genesis, St Augustine pointedly says that the names in it represent 'nations, not men.' ('*Gentes non homines.*' De Civitate Dei, XVII. 3.)

bably to them the invention of printing, the compass, the manufacture of paper and china, and gunpowder, for they were acquainted with these many centuries before European nations were aware of their existence, and they were, or at any rate some of them probably introduced into Europe by Marco Paulo, a Venetian traveller, who visited China A.D. 1275, and the mariners' compass was not invented until A.D. 1302, by Gioia of Naples, and so it is not unlikely that Marco Paulo communicated it to his countrymen. And the art of printing and making paper was not discovered until the fifteenth and eleventh centuries respectively. The Chinese possess, in addition, a vast literature, and have founded and organised a mighty empire, which still continues to endure. *But* everything that the Chinese can do, the Europeans can do much better. It is centuries upon centuries since the Chinese (unaided by Europeans) ceased to improve in anything; they follow rules laid down for them (in government and social life) 3000 years ago or more, with a strictness from which to swerve a hair's-breadth were the greatest blasphemy.

For the last 5000 years the world has been mainly indebted for its progress to the Semitic and Indo-European races. But it was otherwise in the first ages. The working in metals, agriculture, chronology, arithmetic, the childhood, or rather, perhaps, the *infancy* of religion, history, the plastic arts, sculpture, and, perhaps, navigation and astronomy,[1] now appear to have had their origin amongst the Accadians or Turanian Chaldeans.

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[1] We find that, when we examine the claims of the Indians, Persians, and Babylonians as the inventors of astronomy, we are met by this singular coincidence—*their systems of astronomy belong to a latitude much higher than the latitude of Benares, Persepolis, and Babylon*, for the Brahmins teach in their sacred books that the longest day in summer is twice as long as the shortest day in winter, which is not the case in any part of India. So also Zoroaster taught the Persians, and Ptolemy obtained ancient Babylonian records of star-risings, which belonged to latitudes certainly not *lower* than the 40th parallel ; and in the measurement of the earth's circumference adopted by ancient astronomers, it corresponds to a latitude of about 45°, and, taking into account errors of observation, it must have been made between latitudes 35° and 55° north. Now, this latitude of about 40° north is the very latitude in which, in all probability, the most ancient Accadians resided previous to their descent into the plains of Chaldea. This is, of course, a singular confirmation that astronomy originated amongst this people. Amongst the names of their most ancient kings we meet with such titles as, 'Defend O Sun-God,' 'Man of the Moon-God,' 'Man of Samas' (*i.e.*, the Sun), 'Son of Hea (Saturn), king of the earth,' 'Son of Bel (Jupiter), sovereign of heaven,' and in their oldest writing the sign of a star is used to express the divine principle—the deity, generally. Moreover, that their

The beginnings are humble enough, it is true. We may laugh at their rude picture-writing—their spirits and demons, their first attempts at the foundation of science. But 'the first inventors of any art are among the greatest benefactors of their race, and the bold step which they take from the unknown—from black ignorance to discovery—is equal to many steps of subsequent progress.' 'The commencement,' said Aristotle, 'is more than half the whole.' But for their discoveries, the Semites, with their brilliant imaginations and ready conception, could not have given to their early empirical discoveries that tinge of mystery, that touch of poetry, and that religious character that rendered them in after years so acceptable to the analytical and reasoning, but also curiously speculative, minds of the early Greeks. Without this touch of mystery, those astrological fancies and magical formulæ, these same sciences would never have received the acceptance they did, or awakened the interest of the

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astronomy is more *ancient* in all probability than that of those Semites who came into the land of Chaldea not *less* remote than 4000 B.C. is very likely, from the fact that the Semites gave the first place to the *sun*, whilst the Accadians gave the first place to the *moon*, and, of the two bodies, the moon was, we know, the first observed.

Indo-European mind, and such being the case, it should be remembered that the science of astrology (though we now know it to have been a false one) was the beginning of almost all that we hold dear in art, science, literature, and religion. The constellations were the first pictures, and the sun-epic of the Accadian hero, Gishubar, the first poem. Astronomy and mathematics spring almost directly from Chaldean astrology, from which comes indirectly our interest in most of the other sciences.

If the question be asked how it is that a nation, like the ancient Chaldeans, who possessed at so remote a period such a large amount of practical knowledge, did not fail in process of time to make many more discoveries of the same kind, and thus be led on to science founded on a theoretical basis, it may be admitted, I think, that the Chaldeans, subdued successively, as we know they were, by the Assyrians, Persians, and Babylonians, lost by degrees that skill which had so distinguished them in the days of their freedom. The decay of science amongst a nation is generally, if not always, contemporaneous with their subjection, and it was hastened in their case by other circumstances. ‘Poetical, fanciful, and, like all eastern nations, quick in tracing fanciful analogies, the genius of their race led them in early times to choose the heavenly bodies as types of the divine attributes, and in later times as objects of adoration. The planets were regarded with peculiar reverence, and the later Chaldeans reposed undoubted faith in the influence of these orbs on the destinies of men and nations.’[1] Such views proved of necessity a serious check upon their progress. Their astronomical discoveries came, in course of time, to be jealously guarded as sacred secrets, to be revealed to the initiated only, and to them solely by symbols. And this is the chief reason why we know so little in detail what real knowledge or correct statements the early Greeks derived from them. Later, their spirit of inquiry began to be viewed with suspicion and distrust; the Chaldean astronomers contented themselves with handing down the records only of their observations, without discussing how far these discoveries tended to support or to modify the systems they had been taught.

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[1] R. A. Proctor.

A system of science cannot be stereotyped any more than the growth of a tree can be arrested without destroying it. These sciences became in after years the monopoly of the Assyrian priestly caste, who were the slaves of tradition, and, in their absolute and obstinate conventionalism and conservatism, they appear to have been afraid to alter rules or extend the knowledge of their craft. And nothing, we know, is more fatal to all progress than this conventionalism and absolute conservatism. Little change and no progress are synonymous terms.

The later Chaldeans were not indifferent to knowledge, but it was knowledge previously acquired by their forefathers, *i.e.*, it was acquisitive rather than creative knowledge that engaged their attention.

Again, to whatever race the early Chaldeans (and Egyptians) may have belonged, they were afterwards, if not originally,[1] closely to, and greatly composed of Semites. Now, the Semitic race belongs to the occipital races; that is, to those races in which the posterior part of the head is more developed than the anterior, or front part. Their growth is very rapid; at fifteen years of age it has ceased. At that age the anterior portions of his skull, containing the organs of intellect, are firmly brought together, and frequently even cemented to one another. The result is, that no further development of the brain, and especially the grey matter, is possible. This fact, together with the conservatism and conventionalism of the ancient priests, and their subjection to foreign nations, satisfactorily accounts, I think, for their making no further progress in the sciences.

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[1] 'There is,' says Professor Tyler, 'a deep-seated Semitic element in the Egyptian language, only to be accounted for by some extremely ancient and remote connection.'

The changes which take place in an organism are of two kinds—spontaneous action of the organism, and (2) direct action of the environment. To illustrate by an example: Let it be supposed that there was once a race of men that never underwent any changes by means of their spontaneous activity. This race must once have possessed a certain amount of plasticity, or a definite power of adapting itself to different circumstances, by changing in accordance with circumstances. Now, every permanent effect of the environment is a crystallisation of some part formerly plastic; for the part must have been plastic in order to be capable of change, and the effect being permanent, that particular part has lost its plasticity, and become incapable of further change. And, as more and more parts become crystallised, the race will lose more and more its capability of change which it once possessed, till at last it will become entirely crystallised, incapable of change. It must then die out, for the environment must ere long change, and the race, being incapable of changing in accordance with its surroundings, must inevitably perish. Now, on the other hand, spontaneous activity is an addition of something hitherto unacted upon by the environment, and therefore capable of change, and is, therefore, a definite increase of power. That mind, therefore, that would grow, or that race or nation that would wish to hold its own, must be creative rather than acquisitive, allowing no ideas to become permanent in it except those which lead to action. 'It must,' as Professor Clifford says, 'towards all things maintain an attitude of absolute receptivity, admitting all, being modified by all, but permanently biassed by none. To become crystallised, fixed in opinion and mode of thought, is to lose the great characteristic of life, by which it is distinguished from inanimate nature: the power of adapting itself to circumstances.'

No nation that would wish to grow must bow down before its predecessors, as if the discoveries made by them had left none greater behind them; it must study their sciences, their arts, their literature—for the only key to the present is the past; but it must do so not with feelings of trembling and awe, as if such flights of genius had left none higher beyond them; it must remember that there is a Future to be provided for, as well as a Past to be studied. In a word,—

'*It, too, must write Bibles.*'

PART III.

'*Reverence for the past, faith in the future.*'—MAX MULLER.

THE ancient astronomer stood on one of the watch-towers of old Babylon, and wrote the record of an eclipse. This record escaped destruction, and was safely wafted down the stream of time. A thousand years passed by; the old astronomer, surrounded by fierce and wandering Arabs, wrote and again marked the day that witnessed the sun's eclipse. Another thousand years rolled by; once more the astronomer wrote, this time from amidst the gay throng that crowds the brightest capital of Europe. Record was compared with record, date with date, and revolution with revolution, the past and present were compared together, and another victory was won. Thus was solved one of Nature's darkest mysteries.

Note.—Very early in the history of modern astronomy, the suggestion was made that the eclipses recorded by ancient historians should be calculated retrospectively. An unprecedented event rewarded the undertaking. It was found that

The chain of tradition has never been broken. Experience and history teach that our present civilisation has been of very gradual growth, every age retaining recognisable traces of the ones that preceded it. The woodman's axe of to-day still retains much of the form of its ancestor—the stone celt—in its wooden handle; our present grand mathematical notation still retains a record of the early ages when man's ten fingers and ten toes first taught him to count. The very letters with which I am writing these lines can be traced back to the figures of birds and beasts, and other objects drawn by the hands of the ancient Egyptians and Chaldeans, at first as mere picture-writing, to denote only the things represented. The

ancient eclipses could not fully be accounted for without assigning a slower motion to the moon in bygone ages than she has at present. Halley detected what is known as the moon's evection. But no English mathematician was able to cope with the difficulty. Continental mathematicians did no better. Ninety years afterwards Laplace half-solved the difficulty. A new light was thrown upon the subject by the labours of modern travellers and historians. Layard proved Larissa to be the same as the modern Nimrod. Larissa was being besieged by the Persians when an eclipse of the sun took place, remarkable in its effects, and therefore total. Hansen showed that the eclipse of Aug. 15, 310 B.C., not only was total, but also central at Nimrod. This, and nineteen others recorded in the Almagest, have accounted for Hansen's estimation of the moon's motion.

sexagesimal arithmetic of the ancient Babylonians led to the current method of reckoning time. And as it has been with our own sciences, so has it been with our arts, our theology, our philosophy, and, chiefest of all, with regard to our language. Language composed of 'words (which) are the intellectual currency of the world, the counters of thought. The commonest words of daily use have an ancestry that go back immeasurably beyond Alexander, Darius, and the Pyramids. The words *there is* can be traced back, making necessary allowances for wear and tear of language, to the hymns of the Vedas.'[1]

We may go back through the ages, piercing through the clouds and mists of antiquity, and we shall find that the origin of science and civilisation are the same. That from the origin of arithmetic dates the origin of civilisation. Its date is unfixable, and must ever be so; it would be so even if written history extended as far back as the origin of man upon this earth. Who discovered the calculus? Was it Newton or Leibnitz, Cavalier or Fermat; or was it Archimedes, some 2000 years beforehand? Look closely, and you will find that the inventor has always been anticipated, nay, but for this anticipation, we might say that the discovery would never have been made. If, then, there exists this difficulty with regard to a discoverer within the limits of written history, how much more so with regard to events occurring in pre-historic times? Let then its antiquity, its almost incomprehensible antiquity, be sufficient.

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[1] Professor Max Muller.

What a meagre thing it looks, this scientific or exact knowledge of the ancient Chaldeans. *We* could master this knowledge in a few months, the knowledge of the Greeks in a few years, of patient study. But how productive have their early labours been. But for the empirical and technical discoveries of semi-primitive man, the Egyptians, Chaldeans, and later, the Greeks, Arabs, Moors, and Indians, could not have conferred on these discoveries the title of sciences; and, but for their discoveries, Copernicus, Galileo, Kepler, Newton, and Laplace could not have made theirs, and caused the dawn of modern science to break triumphant on the world. The chain of evolution has never been broken; it is perhaps more complete here than elsewhere. The watchword has been ever 'Onward;' the desire (inherited by man from the nations of old) 'Savoir' (to know). Could one of the *savants* of old be aroused from his eternal rest, and enter one of our great observatories or laboratories, and behold the uses of the instruments there collected together; or could he have expounded to him the *Principia* of Newton, or the *Origin of Species* of Darwin, or the *Geometrie der Lage* of Reye, he would experience the sensations, so to speak, of one beholding and listening to revelations from an angel of God.

The *savant* of old was exultant with predicting the *day* on which an eclipse should occur; the modern scientist only rests satisfied when he can foretell long beforehand the precise second when the edges of the respective bodies shall be in apparent contact.

If we, then, in a few years of patient thought and study, can learn far more than our predecessors were able to accomplish in a lifetime, how much have we to be thankful for, how much to rejoice over. We who are the 'heirs of all the ages.' We who have inherited the wealth of thousands and tens of thousands of years of intellectual toil.

Who would prefer to live in the past, though described by the poet as—

> '*Those pure and happy times, the golden days of old.*'

Who does not prefer the age of electricity, of steam, of the telescope and the spectroscope, the telegraph and the phonograph? When man (by the aid of mathematics) can measure an object having a diameter far less than the 120,000th part of an inch, and solve differential equation of the second, and perhaps higher orders, by the mere process of turning a handle; and if we are told that in another fifty years we shall be able to— But enough! could the scientific marvels of to-day been told as a prophecy fifty years ago, they would have dazzled even the most adventurous mind. To discuss the probable developments of the scientific invention of the near future, would be only to bring into play a line of speculation unpermissible even to 'a mathematical enthusiast.'

In conclusion, therefore, we must always remember that there are two 'Debts' that we can never wholly repay:—our debt to the Past, and our debt to the 'Future.' That Future in which

> '*Naught that abides in it*
> *Daunting us—Onward!*

MATHEMATICS AND THE FINE ARTS

OR,

THE UNITY OF SCIENCE AND ART.

> ‘The day of days, the great day of the feast of life, is when the inward eye opens to the unity of things.’
>
> R. W. EMERSON.

MATHEMATICS AND THE FINE ARTS.

INTRODUCTORY.

THE purpose of the following essay cannot, I think, be better explained than by the following passage, and a few remarks on it, taken from a lecture, 'Literature and Science,' by the late Matthew Arnold. In it he says: 'Interesting, indeed, the results of science are, important they are, and we should all be acquainted with them. But what I wish to mark is, that we are still—when they are propounded to us, and we receive them—we are still in the sphere of intellect and knowledge. And for the generality of men there will be found, I say, to arise when they have duly taken in the proposition that their ancestor was a hairy quadruped, furnished with a tail and pointed ears, probably arboreal in his habits, there will be found to arise an invincible desire to relate this proposition to the sense within them for conduct, and to the sense within for beauty. But this the men of science will not do for us, and will hardly even profess to do. They will give us other pieces of knowledge, other facts about other animals and their ancestors, or about plants, or about stones, or about stars, and they may finally bring us to those general conceptions of the universe which have been forced upon us,' says Professor Huxley, 'by physical science. But still it will be knowledge only that they bring us; knowledge, not put for us into relation with our sense for conduct, our sense for beauty, and touched with emotion by being so put; not thus put for us, and therefore to the majority of mankind, after a certain while unsatisfying, wearying.'

And in a similar manner, when the student of mathematics has duly arrived at the proposition that 'any two circles can be inverted into themselves,' or that 'every rational equation has a root,' or at any of 'those general conceptions of the universe' just alluded to, the student of mathematics will still find himself confronting such questions as—science and art, mathematics and poetry, painting and music, are they connected—are they related or not? or, how did the world at large acquire and improve on the ideas of number and figures? How can we span the interval between the savage, who counted only by the help of outward objects, and Newton and Laplace? Or what has mathematics done for the improvement of the human race, and what is it likely to do? In a word, what connection does or does not exist between the abstrusest of sciences and our 'sense for conduct, our sense for beauty?' Can it help us along that most important of all ways—the right guidance of human action, and the road of truth? Can it give us clearer and nobler perceptions of the sense for beauty of which it has been truly said, that, 'it was for beauty that the world was made.' Its utility has been demonstrated over and over again, it is admitted on all hands. But *truth* is higher than usefulness, and includes beauty.

> '*La verité est toute pour tous*
> *Rien de beau que le vrai.*'

If so, then it has an additional claim upon our time and our attention. For we all are, or should be, seekers after truth and beauty, the two essential characteristics of poetry. ‘Poetry,’ says Emerson, ‘which is the perpetual endeavour to express the spirit of the thing, to pass the brute body, and search the life and reason which causes it to exist; to see that the object is always flowing away, whilst the spirit or necessity which causes it subsists.’

Let us, then, in the following pages, endeavour to become—to some extent, at any rate—acquainted with the open secret to the few, but the mystery and stumbling-block to the many—the unity of Truth, Mathematics, Science, and Poetry.

MATHEMATICS AND THE FINE ARTS.

PART II.

'Art might obey, but not surpass.'—EMERSON.

IF we go back many thousands of years in the world's history, and, by the aid of the discoveries of modern science, hold converse with the mightiest and most learned nations of antiquity, we find that those nations who were the greatest at science, *i.e.*, at mathematics, astronomy, and natural philosophy, were they who most excelled in painting, in poetry, in sculpture, and in architecture, and that from those nations also proceeded those three great religious systems which have held unbounded sway over the greater part of earth's inhabitants, from the time of their origin until the present day.

The history of these ancient people is too fragmentary, and presents too many immense gaps for us to say for certain that, in the history of these nations, when science was most widely cultivated, then art attained its culminating point, and that, when science was neglected, art declined. All we can maintain is, that there are indications of this, more particularly in the history of Egypt, which is less fragmentary than that of the Chaldeans. Now, no nation of antiquity having left us any remains (worthy of notice) of the one, without having left us remains (worthy of notice) of the other, and there being indications of an always simultaneous development and decline of both, is a coincidence, to say the least of it, worthy inquiry.

Let us, then, see if this coincidence (we will at present call it so) still continues in the history of the Greeks and later nations. From Grecian history we learn that the famous sculptors, painters, and poets—Stesichorus, Pindar, Æschylus, Sophocles, Euripides, Phidias, Zeuxis, Praxiteles, Apelles, and Scopas were contemporaneous with the great mathematicians, Thales, Pythagoras, Anaxagoras, Hippocrates, Theætetus, Archytas, and Euclid. 'And,' as Professor Spottiswoode has observed, 'it would appear that the culminating age of the classic art was contemporaneous with the first great development of mathematical science, and it would seem that sculpture and painting, architecture and music, nay, even poetry itself, received a new, if not their first, true impulse at the period when geometric form appeared fresh chiselled by the hand of the mathematician, and when the first ideas of harmony and proportion rang joyously together in the morning tide of art.' But more of this anon. Passing on now to the Middle Ages, often termed, from the absence in them of either intellectual activity or goodness, the Dark Ages, we find that the principal sciences and arts of the ancients had indeed been sent into exile, but one department of each was growing up side by side : they were music and the mechanical arts. Science and art were not completely exiled from Europe even during the Middle Ages. The mechanic, not content with so careless a mode of induction as served the purpose of the philosopher, was applying to his art the three great characteristics 'of precision, of exactness, and of proportion.' Pope Sylvester, St Ambrose, Gregory the Great, Charlemagne, Huebald, Guido, etc., were doing the same to music.

Note.—Music as an art begins in the fourth century after

And nearer to ourselves in both time and place, we learn from the History of English Architecture, passing over the round-headed doorways, heavy pillars, and zigzag ornaments of the Norman, the narrow, lancet-shaped, pointed windows, and clustered pillars of the early English, and coming down through the second transition period, to the Decorated, with its enriched doorways, and beautifully arranged mouldings, and its geometrically-traced windows, we find that the last-named period began about the commencement of the fourteenth century. The tenth and thirteenth centuries had seen the introduction of algebra and geometry into Europe, and the thirteenth also saw the beginning of the cultivation of geometry in England, under the auspices of Roger Bacon, etc.

And nearer to ourselves than this,[1] we

Christ. In the year 840 A.D., the organ began to be used in a few churches. Counterpoint was introduced beginning of thirteenth century; Harmony, as a distinct art, was not known until some time afterwards. In the days of Charlemagne (768 A.D.), the French historians describe a clock sent to that monarch by the ever memorable Haroun al Raschid, the Caliph of the East.

[1] See 'The Gentleman and Cabinetmaker's Director,' by Thomas Chippendale, London, 1754; and 'The Cabinet-maker and Upholsterers' Drawing Book,' by Thomas Sheraton, London, 1793.

find that the great school of English constructors of the eighteenth century of the domestic art, both engineers, architects, and cabinetmakers, devoted *half the space* of their books to perspective, and to the principles whereby solid figures may be delineated on paper, or what is now termed descriptive geometry, invented by the French mathematician, Gaspard Mouge, who died 1818. Let us open any book dealing with descriptive geometry, and what do we read? 'That all the drawings must be strictly *mathematical*, perpendiculars and parallels must be accurately drawn, and all dimensions drawn to scale.' Modern investigation has declared that the truth of a curve is the key to the perfection of the classic art; how shall we determine this accuracy? But no other means that I know of save by mathematics or instruments founded on mathematical principles.

The Fillet, the Bead, the Torus, the Scotia, the Ovolo, the Cavetto, the Cyma Recta, the Cyma Reversa of the Romans, are only geometrical figures, formed by different combination of two of the simplest of geometrical curves—the straight line and the arc of a circle. The Echinus, the Cyma Recta, the Cyma Reversa, and the Scotia of the Greeks, are but combinations of straight lines, and the arcs of conic sections, the next simplest curves to the circle.

The Semi-circular Arch, the Equilateral Arch, the Elliptic Arch speak for themselves.

Enough has, I think, already been said to lead you to suspect something more than coincidences in all this. And it is so. Before passing on, however, let us consider one more instance, viz., that of *Perspective.* What did the old Egyptian and Assyrian, and even the Greek art, lack more than anything else? Perspective. Greek art was, however, greatly superior to the Egyptian and Assyrian. It is also in this respect that Japanese and Chinese art is so utterly deficient. Why is this? It is simply because perspective is a branch of geometry and optics. The Egyptians and Assyrians knew but little of these two subjects; as also the Chinese and Japanese. The Greeks knew a great deal about geometry, but little about optics. The moderns know a great deal about *both.* Hence their superiority in perspective. Perspective known to some extent to the Greeks was revived by Albert Dürer, Pietro del Borgo, and Bramantino of Milan (1440), after having become extinct during the disturbance that convulsed Italy, and concerning which Dr Brook Taylor was the first Englishman who discussed it scientifically. Perspective a *sine quâ non* to the painter or designer, though there are many such who regard it as superfluous, affirming that the sketcher or designer has but to make use of his eyes, and *copy justly*, utterly forgetting that it is simply impossible for the painter, and much more so for the designer, to execute a copy of nature with sufficient accuracy by the sole aid of the eye (a most imperfect optical instrument) and the hand; a fact that is also too often proved by many of the sketches exhibited in fine art collections. But to return from this digression.

Note.—It was, indeed, the artist's eye and the artist's pencil that first taught us to see ærial perspective, and it became known to scientific men first through the artist's practical knowledge, and the use made of it in every conceivable representation of light and darkness, of house interiors and exteriors. We have had another application of science in mathematical perspective and optics, and this is the mere fringe of a vast province of science that is utilised by the artist.—*Sir William Thompson.*

The art of the architects of all ages rests upon mathematical principles; and over and over again, in the works of painters and sculptors, does evidence of geometry and mechanics, laid at the foundation, appear, and find itself upwards through the superstructure of their work, and nowhere is this more apparent than in the artistic remains of the great artists of the Cinquecento. And one has only to gaze on a palace or a bridge, a temple or a monument, whether of modern or ancient construction, to perceive that geometry is the handmaid of ornament; the architect, the designer, or the painter cannot do *their* work without a knowledge of practical geometry, for their designs are, in all cases, constructed upon geometrical principles. Wend your way through the streets of any of our important towns, and, if you take particular notice of the ornaments and decorations seen on facias, on doors and gates, and even beneath your feet, in gratings and pavements, you will at once perceive them to be but modifications of geometrical figures. Or enter any of our banks, town-halls, museums, theatres, courts of justice, or churches, and you will find floors of mosaic in geometrical patterns, walls decorated with encaustic tiles, inscribed with ornament, the foundation of which is invariably some geometrical design, and ceilings and corners embossed with regular geometrical figures, often filled in with freehand drawing, and, lastly, windows whose admirable decorations show how freely geometrical tracery has been used in their construction. And, indeed, what is it but the symetrical grouping of geometrical figures, and the systematic combining of beautiful forms which is the greatest charm in architecture and in painting? Now, while not wishing to convey the idea that geometry made the design, we do maintain that the designs of the ancients, when reduced to a system, have been embodied in practical geometry. Having thus shown the intimate connection which exists between mathematics and painting, architecture and sculpture, it remains for us to show the intimate connection existing between mathematics, poetry, and music, or our theory is only half established. This problem is more subtle, and, before we proceed to its solution, we must inquire into, and define exactly, what is meant by the term mathematics, and at what stage of its development a subject may be said to become mathematical.

‘The principles of precision, of exactness, and of proportion are,’ says Professor Spottiswoode, ‘the characteristics of a mathematical phase.’

That which characterises the mathematical phase of a subject, then being precision, exactness, and proportion, mathematics can exist apart from formulæ, and a person might have acquired a great deal of dexterity in the manipulation of formulæ, and yet be no mathematician. Again quoting the same writer, ‘Every subject, therefore, whether in its usual acceptation, scientific or otherwise, may have a mathematical aspect as soon, in fact, as it becomes a matter of strict measurement, or of numerical statement, so soon does it enter upon a mathematical phase. . . . But the real gist of the business does not always lie in the mode of expression, and the fascination of the formulæ, or other mathematical paraphernalia, may, after all, be little more than that of a theatrical transformation scene. The process of reducing to formulæ is really one of abstraction, the results of which are not always on the side of gain; in fact, through the process itself, the subject may lose in one respect more than it gains in another. But long before such abstraction is completely attained, and even in cases where it is not attained at all, a subject may, to all intents and purposes, become mathematical. It is not so much elaborate calculations or abstruse processes which characterises this phase as the principles of precision, of exactness, and of proportion.' The *science* of mathematics is only a language, which enables us to draw correct logical conclusions, according to definite rules, and to express a series of such conclusions in the simplest manner possible by means of lines and symbols, and which gives us the power of deducing truths by means of certain operations with these lines and symbols, furnishing us therefore with an insight into the relations of things formerly obscure or unknown. The natural philosopher proposes to himself the solution of a problem; he endeavours (we will say) to ascertain the laws that govern a given phenomena, the variations it undergoes, and the conditions under which these take place.

If his questions have been correctly put, and all the circumstances (*i.e.*, the *factors* of his formulæ) taken into account, he succeeds in obtaining, by the aid of mathematical processes, a simple expression for the unknown quantity, or relations which has been the object of his search. This expression or formulæ, *translated into ordinary language*, explains the mutual connection of the observed phenomena, or of the experiments which he has instituted, and the formulæ is correct when it enables him to produce a certain series of new phenomena, which are its corollaries. You will thus perceive, I think, how mathematics stand connected with the study of nature, and that, besides mathematics, a high degree of imagination, acuteness, and talent for observation are necessary to make useful discoveries in physical, or, indeed, any other of the sciences, and you will moreover perceive that mathematics is, after all, only an *organon*, an instrumental means of attaining an intellectual habit and qualification for the observation and interpretation of nature—a mighty *organon*, I grant — an *organon* to whose laws the whole domain of science and art are fast becoming subject, but nothing more. 'She does not,' says Professor Spottiswoode, 'indeed contribute elements of fact, which must be sought elsewhere; but she sifts and regulates them; she proclaims the laws to which they must conform if those elements are to issue in precise results. From the data of a problem, she can infallibly extract all possible consequences, whether they be those first sought, OR OTHERS NOT ANTICIPATED; but she can introduce nothing which was not latent in the original statement.'

From the data of a problem she can infallibly extract all possible consequences, some of which may not have been anticipated. The great Newton, when essaying to determine the curve in which a body moves around another in space, subject to the law of gravitation, hoped and prayed that it would turn out to be an *ellipse*—for that was the curve in which the astronomer Kepler had ascertained the planets to move around the sun—found, after he had made the necessary mathematical computations, that he had obtained a mathematical expression or formula, which was not that sought, though resembling it in some respects; it was not the equation to an ellipse, though akin to it. What, then, was his astonishment to find that, on examination, it turned out to be an expression involving all the conic sections, and that a body could so move, not in an ellipse only, but also in a circle, a parabola, and an hyperbola, a conclusion that modern science has fully confirmed, bodies having been discovered moving in all four of these curves. As the painter and sculptor may unexpectedly find themselves face to face with a curve of new discovered beauty, or some grand effect of colouring and perspective, so the mathematician may find himself confronting some new beauty in nature, revealed by the discovery of some great law, or endowing some curve, hitherto only noticed by curious speculators, or utilised by architects and engineers with a higher and a nobler beauty; transforming the arch of the bridge into the orbit of the planet or the comet, the triads of Menaechus into the architecture of the heavens.

The characteristics of a mathematical phase of a subject being then, as we have seen, those of precision, exactness, and proportion, the connection between this science and music (apart from acoustics) lies *in the exactness of the laws of harmony.* For music is an art admitting of even less latitude than either sculpture or painting. The sculptor, for the sake of deepening expression, may trench the laws of form, but the musician seeks higher effects by an unvarying adherence to the laws of his art. 'If he admits a discord,' said a writer,[1] 'it is not as a variation from harmony, but as a denial of it, and it is used to shock the hearer into a deeper sense of the prevailing concord. Nor is any other art so fine in the distinctions it makes. Nothing can be more exact or more minute than the laws of light by which form is revealed, but the eye is not so keen to mark slight departures from the law of form as is the ear in noting variations in its realm. A highly-trained musician can detect a variation from the pitch of one sixty-fourth of a semitone, but the best mechanical eye could not detect a corresponding fine variation of a line from the perpendicular, nor could the nicest sense of colour perceive a like variation in shade.

[1] Theodore T. Munger.

And as the musician must be a mathematician, so must the mathematician be a musician.[1]

'Singing and music,' said Thomas Carlyle, 'was the central principle of the Greeks, not a subordinate one. And they were right. What is not musical is rough and hard, and cannot be harmonised. Harmony is the essence of science and art.'

Turning now to poetry, its first law is, we know, proportion, as harmony is that of music. 'The poetry of Homer,' Carlyle tells us, 'possesses the highest qualities, because it is simple, the impressions of a primeval mind.' The ancients thought that this universe was a little circle of Earth's surface arched over by a star-spangled dome, which was the floor of heaven, and which hid beneath its crystal surface the sulphurous caves of Hades; modern science has shown that this same universe is but infinite space, strewn with an infinite number of infinite suns, and systems of suns, rising in an ascending order of magnitude, from satellite to planet, from planet to sun, from sun to galaxy, from galaxy to galaxy, and so on without end. Danté, Shelley, Goethe, Carlyle, and Emerson, do they and their poetry owe nothing to science? Ay, as surely as science is indebted to them, so surely are they indebted to science. How highly Goethe valued science we know; and he also held that, without the faculty of imagination, no great naturalist could exist. When had the poet such powers at his commands as at the the present day? When was his imagination allowed such daring and sure play? When did he dwell amid such conceptions, conceptions which do indeed 'beggar those of Milton?'[1] Mathematics and poetry are one. By poetry I do not mean rhymes, rattles, ding-dongs, or barbaric word jingle; but all those records of the happiest and best moments of the happiest and best of minds that the world has acquired up to the present time, no matter whether it be contained in the *Paradise Lost* of Milton, or the *Geometrie der Lage* of *Reye;* in the *Prometheus Unbound* or the *Fundamenta Nova.* 'Physical investigation (or mathematics, for they are in reality one),' said a writer,[1] 'more than anything besides helps to teach us the actual value and right use of the Imagination, of that wondrous faculty which, left to ramble uncontrolled, leads us astray into a wilderness of perplexity and errors, a land of mists and shadows, but which, properly controlled by experience and reflection, becomes the noblest attribute of man; the source of poetic genius, the instrument of discovery in science; without the aid of which Newton would never have invented fluxions, nor Davy have decomposed the earth and alkalies, nor would Columbus have discovered another continent.' The imaginative or poetic faculty has *ever* been (when properly controlled by experience and reflection) the great discovering power. Those lines of Wordsworth are literally true when speaking of,—

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[1] Even the very cords of our pianos are strung upon one of the curves known as the conic sections.

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[1] 'The poetry of old is built on dream—
  A dream of beauty never coming true!—
But Science shadows forth the nobler theme
  Of wondrous Nature; be it sung by you!
Science and Nature, waiting hand in hand,
Now on the threshold of the New Day stand.'
THEODORE WATTS.

> '*Chaldean shepherds, ranging trackless fields,*
> *Beneath the concave of unclouded skies*
> *Spread like a sea in boundless solitude,*
> *Look on the polar star as on a guide*
> *And guardian of their course that never closed*
> *His steadfast eye,* . . .

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[1] Sir David Brodie.

In which he says

The imaginative faculty was lord
Of observation natural. . . .'

But it must be an imagination controlled in the manner described above, the imagination without mathematics expressed or implied is only a source of wilderness and error. Mathematics without imagination could never have come into existence; the one is mutually dependant on the other. Poetry, painting, architecture, and even the kindred arts of Music and Literature, if properly probed, are not less dependent on the science of mathematics. 'For what,' says Professor Spottiswoode, 'in fact is logic, but that part of universal reasoning; grammar but that of part of universal speech; harmony and counterpoint but that of universal music, "which accurately lays down," and demonstrates (so far as demonstration is possible) precise methods appertaining to each of these arts.'

Science and art are one, and as such should they be studied; and let no one hope to make any discovery of importance, or to gain true knowledge, who studies one and neglects the other, for one they were and are, and must remain, and be not deceived by that false assertion (so often made) that great men have always been men of one-sided culture only. Nothing could be more untrue. Euclid, Plato, Pythogoras, D'Alembert, and Euler were writers on music; Sir William Herschel was originally a poor organist; the great Greek scholar, Porson, was proficient in algebra, and liked it; Laplace, Newton, Lagrange were able classicians as well as mathematicians; Clifford wrote poetry; Tydall's fondness for poetry is well known.[1]

The sculptors and painters of the middle ages were not only sculptors and painters, but also architects and engineers. Giotto, and even Michael Angelo himself, were two of the architects of St Peter's Rome. The story of how Giotto became one of the architects of this famous cathedral is not without interest. When Benedict XI. was Pope of Rome, artists were wanted to work at the decoration of the great cathedral, and invitations were sent to the principal painters of Italy to forward specimens of their skill for the Pope's inspection. Giotto contented himself with drawing a *circle* on a piece of paper with a bit of charcoal, and handing it to Pope Benedict's messenger. It was in vain that the messenger urged that his master required some design as a specimen of Giotto's skill, for the painter refused to send anything else. The circle so hastily drawn was found to be perfect when tested with a pair of compasses, and so struck was the Pope and his advisers with this surprising proof of the artist's capacity as a draughtsman, that he was immediately summoned to Rome to carry out the work that Benedict wished to contribute as his quota to the adornment of one of the finest cathedrals hitherto built.

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[1] Alexander, Cæsar, Charles XII., Buonaparte, and the two celebrated military engineers, Vauban and Coehorn, were profound geometers.

It has often been observed of Tyndall, Darwin, and Spencer, who have done no independent mathematical work, that they have been pre-eminently mathematical in their manner of working and thinking, and that they might have been eminent in mathematics; and few would dare to say, I should think, that Sebastian Bach too would not have been eminent in that science. His fugues surely possess the three characteristics of 'precision, exactness, and proportion.' But few, even at the present day, I believe, realise the important part that the science of mathematics has played, both directly and indirectly, in the history of human progress, and the important service which a mathematical turn of mind is capable of rendering, even where no mathematics may be employed or required;[1] and especially has it been so with regard to art.

When Pascal's father had forbidden the study of mathematics, and closeted him with Greek and Latin, he found on his return the walls teeming with formulæ and figures, the more congenial product of the boy's mind. 'Fortunately,' as Professor Spottiswoode says, 'for the boy, and fortunately for science, the mathematics were not torn up, but were suffered to grow, together with other subjects. And, all said and done, the lad was not the worse scholar or man of letters in the end.'

As we have before said, from those nations from which the science of mathematics proceeded, arose also those three great religious systems which have held unbounded sway over the greater part of earth's inhabitants, from the time of their origin until the present day. And the science of mathematics has been most closely interwoven with religious impressions from the time when—

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[1] Xenocrates, the master of Aristotle, said to one who wished to be his auditor, but who knew nothing of geometry, 'Go thy way, for thou wantest the very handles of philosophy.'

> ‘*The trees,*
> *The grass, the mountains, and the sea,*
> *All living things that walk, swim, creep, or fly,*
> *Were gods.* . . .’

and when

> ‘*The sun had homage, and the moon*
> *Her worshippers.*’[1]

And from the origin of arithmetic dates the origin of the birth of religious impressions. For then commenced the beginning of all abstract thought; for number is a principle common to really every branch of learning, giving distinctness to expression, and clearness of thought to ideas then floating in untutored minds, and suggesting to them new conceptions; in ‘the one,’ ‘the all,’ ‘the many in one;’ terms of purely arithmetical knowledge, ‘It gave,’ says Professor Spottiswoode, ‘the earliest utterances to man’s first crude notions about God and the world. In ‘the equal,’ the ‘solid,’ the ‘straight,’ and the ‘crooked,’ which still survive as figures of speech amongst ourselves; it supplied a vocabulary of speech for the moral notions of mankind, and quickened them by giving them the power of expression. In this lies the great and enduring interest in the fragments which remain to us of the Pythagorean philosophy.' The Pythagoreans considered number to be the basis of creation; number to them was quantity, and quantity was form, and form was quality. It was to arithmetic that Pythagorus looked for his definitions of all abstract terms, and his explanation of all natural laws. Having learnt in Egypt and Babylon that number was essential to the exact descriptions of forms, and the relations of forms, he concluded that number was the *cause* of form, and so of every other quality. 'The Axioms of Physics,' said Emerson, 'translate those of Ethics.' Admission to its sanctuary (*i.e.*, the temple of science), and to the privileges and feelings of a votary,' said Sir John Herschel, 'is only to be gained by one means—*sound and sufficient* knowledge of mathematics, the great instrument of all exact inquiry, without which no man can ever make such advances in this (*i.e.*, astronomy), or any other of the higher departments of science as can entitle him to form an independent opinion on any subject of discussion within their range.'

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[1] Shelley.

As to what the future of art and science will be, since man has at length learnt the correlation of the sciences, and the unity of science and art, no man can predict. Bonavia Hunt, in his 'History of Music,' concludes with the following remarkable words :—'There is, however, another and distinct class of musical philosophers, whom we call the SCIENTISTS of the present day, men whose researches as physicists have led them into a special inquiry into the laws and phenomena of sound. To this class belong Wheatstone, Tyndall, Blaserna, and many whose names must be familiar to every reader of contemporary musical literature. But undoubtedly the most distinguished amongst musical scientists is HELMHOLTZ, the German physicist and physician, whose work, '*Die Lehre von den Tonempfindungen*,' recently translated into English by Mr A. J. Ellis, has opened, as it were, a new world to the new view of the musicians. . . . It may be that at any moment, while the pen is in the hand, or the lips are moved to speak some sudden burst of light, some new and splendid apocalypse, shall, by the instrumentality of science, irradiate the whole world of music, revealing forms of beauty and spheres of vision hitherto beclouded and unknown.'

The highest aim of all culture at the present day is to attain to a clear perception of this all-dissolving and all-embracing unity, and the greatest of all truths is to know, with Emerson, that,—'That day of days, the great day of the feast of life, is when the inward eye opens to the unity of things.'

THE END.

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58. [illegible]
61 Medicine a dermatology